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American Welding Society

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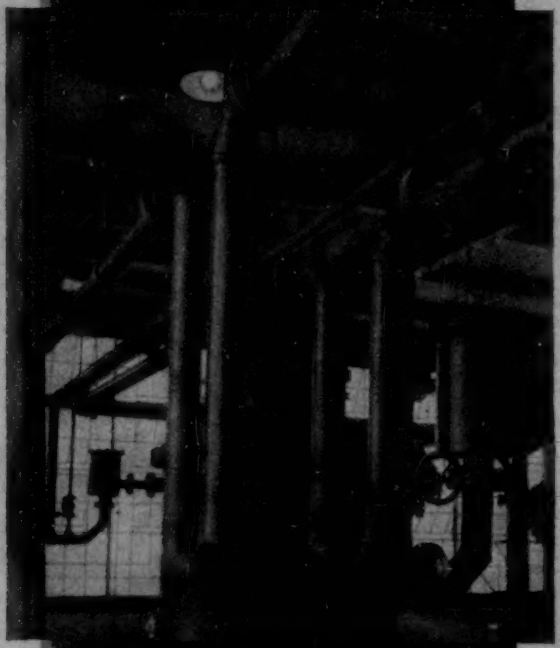
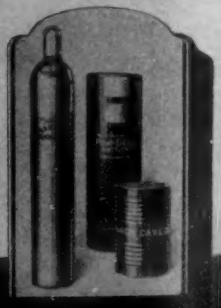
WELDED Industrial Piping



"Proper methods of inspection and procedure control have been established and are available to all interested; so there is no longer any excuse for poor work. Welded lines are often cheaper in first cost, and are invariably superior in the matter of tightness."

—From an Editorial in POWER



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JOURNAL

of the

AMERICAN WELDING SOCIETY

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933 *Bay Street, Toronto*

Chairman—Fred H. Williams, Canadian National Railways
Secretary—Campbell Bradshaw, Executive Editor, Engineering Times, 933 Bay Street, Toronto

AMERICAN WELDING SOCIETY
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JOURNAL

Volume 8 JULY, 1929 Number 7

PROGRAM

1929 FALL MEETING

of the

AMERICAN WELDING SOCIETY

to be held in

CLEVELAND, OHIO, September 9, 10, 11, 12 and 13, 1929

Morning Sessions at Hotel Statler
Afternoon Sessions and Exposition at Public Auditorium
All sessions start promptly as scheduled

IMPORTANT NOTICE

Members and their guests are requested to register, as admission to the Public Auditorium and some of the social events will be by badge only.

MONDAY, SEPTEMBER 9, 1929

Morning

Registration—Registration facilities will be provided for members and guests at the Hotel Statler, commencing Monday, September 9, at 10:00 A.M., and at the Public Auditorium, commencing Monday at 12:00 M.

Afternoon

Meeting of Board of Directors, American Welding Society, 2:00 P.M., Hotel Statler.

TUESDAY, SEPTEMBER 10, 1929

Morning

Business Session

10:00 A.M., Hotel Statler, F. T. Llewellyn, President, Presiding.
This will be in the nature of a few introductory remarks by President Llewellyn and transaction of any formal business or introduction of local celebrities.

Technical Session

10:30 A.M., Hotel Statler, A. E. Gaynor, Vice-President, Presiding.
The Effect on Design of the Use of Welding in the Manufacture of Electric Machinery, by H. G. Reist, General Electric Company.
Cutting and Welding Steel Parts to Replace Castings, by W. F. Buchanan, The Bessemer Gas Engine Company.

TUESDAY (Continued)

Tuesday Afternoon

Technical Session

2:00 P.M., Public Auditorium, H. L. Whittemore, Vice-Director American Bureau of Welding, Presiding.

Welding of Copper and Copper Alloys, by I. T. Hook, Research Laboratory, American Brass Company.

How to Test Welds, by F. G. Tatnall, Southwark Foundry & Machine Company.

Evening

9:00 P.M., Cleveland Hotel, Metal Congress Dance.

WEDNESDAY, SEPTEMBER 11, 1929

Morning

8:30 A.M., Starting from Hotel Statler, Inspection Tour of three plants.

10:00 A.M., Hotel Statler, Conference of research workers on Fundamentals of Welding, H. M. Hobart, Chairman, Presiding.

Afternoon

Technical Session

2:00 P.M., Public Auditorium, J. J. Crowe, Member Executive Committee, A.W.S., Presiding.

Study of Nitride Needles, by P. Alexander, General Electric Company.

Chemical Reactions of the Carbon Arc, by G. E. Doan and E. Ekholm, Lehigh University.

A Metallographic Study of Some Metal Arc Welds, by H. M. Boylston, Case School of Applied Science.

Metallographic Studies of Welding and Cutting, by M. Yatsevitch, Watertown Arsenal.

Evening

7:30 P.M., Hotel Statler, J. H. Edwards, Chairman, Presiding.

Meeting of Structural Steel Welding Committee.

THURSDAY, SEPTEMBER 12, 1929

Morning

Technical Session

9:30 A.M., Hotel Statler, F. T. Llewellyn, President, Presiding.

Motion picture on "Gas Welded Steel Building."

Gas Welding of Steel Building, by H. H. Moss, Linde Air Products Co.

Non-destructive Testing of Welds with the Stethoscope and X-Ray, by C. O. Burgess, A. B. Kinzel and A. R. Lytle, Union Carbide and Carbon Research Laboratories.

Welding Studies at the Watertown Arsenal, by Major J. B. Rose, Ordnance Dept., U. S. A.

Stress Strain Characteristic of Welded Joints, by J. H. Smith, University of Pittsburgh.

Afternoon

Joint Technical Session with A.S.M.E.

2:00 P.M., Public Auditorium, C. A. Adams, Director American Bureau of Welding, Presiding.

Foreign Practice in Welding of Boiler Tubes and Drums, by G. A. Orrok, Consulting Engineer.

Automatic Arc Welding of Thin Sheets, by W. L. Warner, General Electric Company.

Non-destructive Tests of Welds, by Elmer A. Sperry, Sperry Development Co.

Evening

Annual Banquet and Dance

6:30 P.M., Hotel Statler, Annual Banquet and Dance.

FRIDAY, SEPTEMBER 13, 1929

Morning

10:00 A. M., Hotel Statler, J. C. Lincoln, Past Chairman, Cleveland Section, A.W.S., Presiding.

Oxy-acetylene Welding of Pipe Lines in the Field, by W. R. Ost, Air Reduction Sales Company.

Electric Welding of Field Joints of Oil and Gas Pipe Lines, by H. C. Price, Welding Engineering Company.

Welding of Tubing and Pipes for Locomotives and Boilers, by H. A. Woofter, Swift Electric Welder Company.

Afternoon

American Bureau of Welding

2:00 P.M., Hotel Statler, Prof. C. A. Adams, Director, Presiding.

Meeting of American Bureau of Welding.

LADIES' ENTERTAINMENT

MONDAY, SEPTEMBER 9, 1929

Registration 11:00 A.M. at Hotel Statler after which they will be transported to Hotel Cleveland for automobile ride, leaving Hotel Cleveland at 11:30 to Country Club for luncheon and entertainment. On return visit Art Institute.

TUESDAY, SEPTEMBER 10, 1929

Luncheon at Chamber of Commerce in Terminal Building. View of city from Terminal Tower and card party in afternoon.

Evening

Metal Congress Ball

WEDNESDAY, SEPTEMBER 11, 1929

Theatre Matinee

THURSDAY, SEPTEMBER 12, 1929

Automobile tour through City of Cleveland. Luncheon at Nela Park.

Lecture on house lighting and decorative schemes for use of lights and light appliances. Returning by different route to hotel.

Evening

Annual Banquet and Dinner Dance, American Welding Society

STRUCTURAL WELDING MEETING
BOSTON SECTION, AMERICAN WELDING SOCIETY

OCTOBER 10, 1929

To be held at Massachusetts Institute of Technology under the auspices of the Affiliated Technical Societies of Boston

All manufacturers interested in the art of welding are invited to take part in the exposition to be held under the auspices of the Affiliated Technical Societies of Boston, by the Boston Section of the American Welding Society, at the Massachusetts Institute of Technology on Oct. 10, and those who wish to exhibit their apparatus or supplies are invited to get in touch with Mr. R. L. Browne, 1038 Statler Building, Boston, as soon as possible.

PROGRAM

The meeting will be opened by Mr. C. W. Babcock, chairman of the Boston Section, and will be presided over by President Llewellyn of the Society. Addresses of welcome will be given by Dr. S. W. Stratton, president of Massachusetts Institute of Technology; Prof. E. F. Miller, Massachusetts Institute of Technology, and by Mr. Alfred Kellogg, chairman of the Engineering Societies of Boston.

Papers will be presented on "Electric Arc Welding," by Prof. F. P. McKibben, consulting engineer, and by Mr. A. M. Candy, Westinghouse Electric & Mfg. Co. These will be followed by papers on "Gas Cutting of Steel," by Mr. J. J. Crowe, Air Reduction Sales Company, and paper on "Fabrication," by Mr. P. J. Horgan, of the River Works Plant of the General Electric Co., West Lynn. There will be demonstrations of Gas Steel Cutting, Arc Welding of Trusses, and Testing of Welds to Destruction.

National Metal Congress

Cleveland, Sept. 9 to 13

(News Release)

During the week of Sept. 9 five leading technical societies — American Welding Society, American Society for Steel Treating, Iron and Steel Division, A. I. M. E., Institute of Metals Division, A. I. M. E., Iron and Steel Division, A. S. M. E.—will hold their annual meetings in Cleveland simultaneously. These societies have a combined membership of over 15,000. At the technical meetings of these societies, to which you are invited, internationally recognized authorities—over 150 of them—will read papers which will touch on practically every phase of the production, fabrication, treatment, welding and use of metals of every kind. These papers will bring together in one place and at one time every important new development in the metal industries. To attend those technical sessions which touch in any way upon your own problems is to assure yourself of the latest, most authoritative knowledge on the subject. In one week's time you can gain more practical, working facts than could be obtained from text books in a year's time. Neither you nor your key men —engineers, plant manager, superintendent, technicians—can afford to miss this year's National Metal Congress—the most educational, the most authoritative, the most important event of the year in the metal world.

National Metal Exposition

Concurrently with the annual meetings of the five technical societies, there will be held in the

Public Auditorium, Cleveland, the Eleventh Annual Metal Exposition

Over 275 manufacturers will exhibit the latest equipment, supplies and the newest processes and methods that

have to do with the making, working, treating, welding and use of every kind and form of metal. These exhibits, many of which will be in operation, will cover over 80,000 square feet of floor space. From them you are certain to get many new ideas—ideas that will mean reduced labor costs, shortened production hours, faster ways of handling materials, a better product. By combining attendance at the technical sessions and a thorough study of the exhibits you cannot help but get at least one idea that will pay many times over the cost of your trip and the trip of every key man you bring with you. As you are invited to the technical sessions so are you invited to this exhibit.

Plan Your Trip

The technical sessions of the societies have been so arranged that there will be practically no conflict between sessions covering similar subjects. In this way you or your engineers, production and research men will be able to get all possible information and data on the subjects in which you have your greatest interest.

Bring Your Key Men

There is no better way to secure the enthusiastic and whole-hearted cooperation from your men on the firing line than to let them help you in finding the ideas that will make your company — their company — a more successful, more aggressive, up-to-the-minute organization. So don't forget to send every key man in your organization whose work touches on the selection of material, the production, fabrication, treatment, welding or use of metals.

Plant Inspection

To make the National Metal Congress of the greatest practical value, plant inspection trips through many of Cleveland's most modern plants have been scheduled. These trips offer an unusual opportunity to see how the other fellow does it—to study in actual, practical operation how production schedules are speeded up, how time and labor savings are effected. A complete list of these plant inspection trips will be given in the National Metal Exposition program.

Finding and Encouraging Competent Men for Scientific Research in Industry*

By Dr. F. B. Jewett,

Vice-President American Telephone & Telegraph Company; President Bell Telephone Laboratories, Inc.

"Except in those details which are the direct consequence of a particular function, the problem of finding and encouraging competent men in industrial research is in no substantial measure different from the finding and encouragement of competent men in any walk of life."

* * *

"The rank and file of the modern industrial research organization are relatively easy to find, though sometimes difficult to get in sufficient numbers."

* * *

"A man is essentially miscast and essentially a transient if he finds himself in a field of endeavor where the primary requisite for success is alien to the thing he most desires."

* * *

"In both pure science and industrial research the men who succeed will be, for the most part, those men in whom the element of curiosity about nature and her ways is a controlling urge."

* * *

" . . . the problem of finding competent men boils down, in the last analysis, to our ability to find competent young men—to bring them into the organization, provide them with the facilities and encouragement for growth, and ultimately to make leaders of them."

* * *

" . . . when competent men come to us we can see to it that their surroundings, the conditions of their association with their fellows, and the tools with which they work are congenial and adequate. Above all, we must see to it that a just recognition of their achievements is accorded them."

*Excerpts from recent speech before the American Association for the Advancement of Science, taken from *Electrical World*, March 23, 1929, edition.

Pennsylvania Cities May Now Weld Buildings

An increase in the use of welding in the construction of buildings in the State of Pennsylvania is foreseen as a result of the passage by the Legislature of that State of a law which allows this type of construction to be used in first-class cities. The new law gives in detail a building code for cities of the first class and in this code is a section giving permission to commissioners of buildings in such cities to adopt welding as an erection method.

Structural Welding Assurance

(Reprinted from July 18th issue of Engineering News-Record)

In drafting a code for structural welding, the American Welding Society has performed an outstanding service for the engineering profession as well as for welding itself. The engineer who has been called upon to design a welded structure has been involved in serious doubts because of a lack of guiding specifications. The guesswork to which he had to resort created a potentially dangerous condition for welding progress.

It is a criterion of modern engineering that such dangers as this are combated not by closely guarding all information as did the old-time craftsmen's guilds, but by making it universally available. This practice, on the part of advocates of special engineering methods, of early codification of data and constant elaboration and study by research is apparently growing. Such information is increasingly necessary and whenever provided is welcome indeed.

The new code is brief, but it supplements brevity by reference to the more voluminous data compiled by the structural steel welding committee. It sticks to fundamentals, and quite definitely delegates the task of providing safe and economic structures to the judgment of competent engineers. Perhaps some of the "shall" clauses in its section on design might better have been tempered by the substitution of one or two acceptable methods. Also, it is not clear why the code is confined so rigidly to buildings, although a bridge code may have been regarded as premature in view of our limited knowledge of how welded joints act under impact. But by and large the framers have succeeded in developing an authoritative and impartial code that should prove of great value.

At the same time, having created a code which relies upon competent engineers to carry it out, the society has assumed an obligation to insure the proper development of such men by providing them with interpretation of all data on tests and practice as they become available. One of the first tasks would seem to be the enlargement to actual job proportions and needs of the test specimen data already compiled by the structural steel welding committee. With the new code available, and with a continuing research program going on, structural engineers can now look on welding with increased confidence that they will be able to make proper and safe application of its possibilities.

In Memoriam

Professor Peter Gillespie, who from the beginning has been closely identified with the Structural Steel Welding Committee of the American Bureau of Welding, succumbed to a heart attack on May 26, 1929, at the age of 56. He was an outstanding figure in the engineering profession of Canada and a leader in research activities. Under his supervision a series of pilot tests were made for the Structural Steel Welding Committee, and which enabled the committee to modify its program and to be assured of its practicability.

At a meeting of the Executive Committee of the American Welding Society, held in the Engineering Societies Building, New York, N. Y., on the fourth day of June, 1929, the following resolutions were unanimously adopted:

Whereas: The Executive Committee of the American Welding Society has learned with profound sorrow of the death on May 26 at his home in Toronto of Peter Gillespie, Professor of Civil Engineering in the University of Toronto, Canada, and

Whereas: The members and officials of the American Welding Society recall with deep appreciation the welcome part that Professor Gillespie always took at its conferences, and, in particular, the generous assistance he

rendered to its Structural Steel Welding Committee in the form of practical research, and

Whereas: It is believed that the passing of this great-hearted man will leave a marked vacancy in the ranks of true engineers and valued friends; therefore, be it

Resolved: That the members of the Executive Committee of the American Welding Society hereby express their deep regret and sense of loss in the death of Peter Gillespie and their appreciation of his services in the American Welding Society, and, further, be it

Resolved: That these resolutions be spread upon the records of the Society and copies be sent to his family and to his associates in the University of Toronto as an expression of our mutual loss and sympathy.

SECTION ACTIVITIES

Chicago

On May 3 the Chicago Section held a very interesting meeting, which was devoted to the subject of "Profitable Ideas for the Job Welder," and a very lively discussion followed. Through the courtesy of the General Motors Company their two reel film "Proved" was shown. This film was of extraordinary interest and showed the many tests that General Motors' cars are put through before they are finally put on the market.

Northern New York

This Section held a Railroad Meeting on May 6. The lecture was on "The Application of Electric Welding to Railroad Work," and was given by Mr. B. S. Cain of the Railway Equipment Engineering Dept., General Electric Company.

Philadelphia

The May 20 meeting of the Philadelphia Section was given over to a paper on "Welding in Ship Construction" by Mr. J. W. Owens of the Newport News Shipbuilding and Dry Dock Co.

San Francisco

The April meeting of the San Francisco Section was held on the 19th. Through the courtesy of the Union Carbide and Carbon Corporation a most interesting moving picture film was shown.

The first reel was an animated picture describing the operations of the oxy-acetylene welding and cutting torches and touched lightly upon oxygen and acetylene cylinders and also the workings of carbide generators.

The second reel covered production welding in industry.

The third reel covered the airplane manufacturing industry.

The May meeting of this Section was held on Friday evening, the 24th. Mr. R. M. Alvord of the General Electric Company gave a general outline of the California Uniform Building Code which is being prepared.

Mr. J. B. Leonard, Superintendent of Building, San Francisco, discussed the sections of the code relating to the welded frames of buildings.

The June meeting was held on the 28th. Mr. R. O. Waldman of the Fusion Welding Corporation presented a very interesting moving picture film, "Study of the Flow of Welding Metal."

The members of the Section were invited by the Electrical Development League to attend their meeting, which was held on the 8th. The new General Electric film with sound effects was shown. The speaker in the movie was Dr. Langmuir. The film showed the different applications of atomic hydrogen welding. This was an excellent program, and member of the Section were able to see the latest developments in welding.

Employment Service Bulletin

POSITIONS VACANT

V-45. Engineer and welder of many years' practical experience, as manager of modernly equipped Welding & Radiator Co., Inc., New Jersey, 30 miles from New York, fast growing town of 20,000, old established and going concern, seek associate with similar experience and ability, as executive and business promoter for expansion. Must have capital to acquire financial interest. State experience, age and references.

Discussion of Technical Papers Presented at Annual Meeting of American Welding Society

WEDNESDAY MORNING SESSION

C. A. McCUNE, Presiding.

Discussion paper on "Training Welders"* by L. S. Thurston, General Electric Co.

Mr. L. S. Thurston: Mr. Chairman and Gentlemen: During the several years that I have been connected with welding, largely in the commercial end, I have felt very strongly that no matter how processes are developed or how machines are designed, the ultimate result depends entirely upon the operator. What I tried to bring out in my paper is that unless operators are thoroughly trained and are reliable, conscientious workers, the art of welding is going to be hindered.

I have sketched a curve of the growth of welding which is based largely upon sales of equipment and that information has been gathered from statistics rendered through the reports of the National Electrical Manufacturers Association and the Census Bureau, and it shows a very distinct upward growth. There is no appearance yet of the familiar S form where the curve starts to flatten off. It is still shooting upward.

Unless the operators, the men who actually do the welding and those who supervise welding are trained to do a conscientious and thorough job, there may be a recurrence of that loss of confidence in welding which occurred a few years ago. What I would like to see would be some national organization, such as the American Welding Society, adopt a program for training and qualifying welders, having some standard whereby the user of welding, the man who hires welders, could be fairly certain that the men employed were going to do a good job. If those men could exhibit a diploma or a certificate of some sort showing how they were graded on some standard forms of grading, their employer would be reasonably certain that he was hiring a skillful man.

In the suggested qualifications under Item II I have classified "reliability of the operator" practically on the same basis as "quality of work," and in reading over some of the other papers which have been presented, I notice that same point has been emphasized. If a man is not reliable and conscientious in his work, he is not going to do a good welding job. There will be failures, resulting in a loss of confidence and the welding industry must suffer.

*Paper published in April, 1929, issue of Journal of A. W. S.

Professor C. A. Adams, Harvard University: The American Welding Society may perhaps play an important part by providing standards or specifications under which welders should be tested.

Discussion paper on "Organizing and Operating an Industrial Welding School,"* by C. E. Conway, Educational Director, Bedford Branch, Y. M. C. A.

Professor Adams: I would like to ask Mr. Conway what the license is he refers to.

Mr. **Conway:** The license given by the City of New York.

Mr. **F. W. Taft,** Passaic Bergen Welding Works: I would like to ask Mr. Conway what the cost to the student is.

Mr. **Conway:** The tuition is $66. The students pay for the course in weekly payments. If they pay cash, there is a 10 per cent discount. That includes a year's membership in the Y. M. C. A.

Mr. **Taft:** Is that for the general course or just one particular branch?

Mr. **Conway:** That is for the general welding course. That pays for fourteen 3-hour sessions of welding, where a student has a welding torch in his possession all of those 42 hours.

Mr. **Taft:** Do you find that you can produce a welder of any note at all with that many lessons?

Mr. **Conway:** No. That is the most difficult thing for a school to decide. The men who come to take a welding course, as a rule, have very little money and they want to become a welder overnight, and we have to do the best we can for them.

Mr. **Taft:** The reason why I ask that question is because I conduct a small school out in New Jersey on pipe welding only and we give 15 practical lessons and five theory lessons and we charge $50 for the course, and I know that it is sometimes difficult to get the $50. We devote the entire 15 lessons to just pipe welding, just the one branch of the industry. In the fall we expect to inaugurate a course on the airplane industry separately.

We also find that we have the union proposition to contend with. The unions out there have absolutely no welders. When they want a welder out in New Jersey the nearest point is Jersey City and then there is a very limited number.

We found that we could not supply welders for union shops because we were running a job welding shop. I took the question up with the union authorities in our locality and they seemed to be very much enthused about it. They are very anxious to get men that really will be qualified.

Mr. **Conway:** I might mention the fact that when a man enrolls for 14 three-hour sessions of welding he may take this general welding

*Paper published in June, 1929, issue of Journal of A.W.S.

course that I outlined to you or he may spend those entire 14 sessions on pipe welding. The local in New York has sent us a number of union steamfitters and in some cases the union pays for the tuition of those men. We also give instruction in airplane welding. In that case the entire 14 sessions are devoted to only two things: teaching the man to weld seamless steel, such as is used in fuselages and training him to weld sheet aluminum used for the gasoline tanks.

Mr. E. A. Abrahams, U. S. Welding Co., Inc.: Do you ever have occasion to trace these men when they get through?

Mr. Conway: We get calls for men from time to time. The men have sufficient training to get their license and also sufficient training to hold down a job providing the employer understands that they are not to be paid full salary.

Mr. Abrahams: In other words, they are helpers instead of welders; is that the idea?

Mr. Conway: Some go in as helpers and some go in as welders, but in no case would the employer pay much wage to them until they have additional outside experience. The same thing, I think, is true in practically all school training to a greater or lesser extent. A man going to a technical university spends four or five years there and obtains a degree, but it takes some years of outside training before they are real honest-to-goodness engineers.

Mr. Abrahams: Do you personally feel after 14 lessons a man is qualified to call himself a welder?

Mr. Conway: Not enough to brag about it.

We get a type of man who has little or no education. He is working possibly as an elevator man or as a shipping clerk. But he has ambition. He wants to get ahead in the world. We will give them a limited amount of training. That doesn't make an expert welder out of them, but it does get them up to the point where there are some employers who are willing to give them a chance to get ahead.

Mr. Abrahams: I personally think that it is perfectly asinine for an organization like our pipefitters' union to send men to a welding school and in the course of 14 lessons expect them to go out and do a pipe welder's job. It would probably give him a foothold on the fundamentals of what welding constitutes, but not capable of going out and doing a pipe job. I have trained men but I have taken years to do it. I made real welders of them but it takes many months of intensive application and practice before they can become adaptable to the trade.

Mr. Conway: On the other hand, there are some men that take to welding like a duck takes to water. We have men like Thomas, the welding foreman for the Curtiss Corporation, who comes from time to time at night and gives instruction to our welding students on airplane welding. Madison, the fuselage foreman of the Curtiss Corporation, gives training on fuselage repair, which includes welding. We actually rebuild cracked-up fuselages. If you would visit the school

some time I could show you some jobs turned out by students that are really honest-to-goodness jobs. Some of the men really take to it very quickly. Others are hopeless. We have had men take the course and when they have had a few lessons the instructor comes to me and says, "This man will never make a welder," and I will go to the man and talk to him like a father and get him to transfer over to some other course and tell him he is in the wrong pew.

Mr. Abrahams: I think that is a very good thing to do because every man that takes up welding can never be a welder. If a man is misplaced, it does hurt the industry.

Mr. Conway: There is a lot of feeling against trade schools because they have to give comparatively short courses and they can't get men to come there and stay four years like the universities can. If we could, we would turn out honest-to-goodness men at the trades. We get the type of men who only have a small amount of money, and the idea of staying four years or even one year in a school never occurs to them; they haven't the patience; they are not that type.

Of course, a lot of men will take a trade course and go half way through and then their little flare of ambition dies down. On the other hand, some good material comes to a trade school with just as much manhood and real grit as will go to the universities. When we get that type we can make something out of them.

Mr. Taft: We had 12 men in a group and I noticed one man in particular the first evening he arrived there. As Mr. Conway said, he had that extra ambition that some of them have and the others don't have. This fellow worked in a mill doing ordinary labor—checking, I believe, of some sort. He came in and said, "I want to be a welder." He had the same idea that most of them have that he was going to be a welder right away. I told him we didn't make welders. All we did was to show them the fundamental principles and it was entirely up to them to make welders out of themselves. This fellow dug in and at the end of the course we had a little blowout, a little dinner to create a little friendly spirit among them and I offered a prize. The first prize was a "Welding Encyclopedia" which you all probably have seen. This fellow won that first prize. He made the best sample. I had them make up a 2-in. pipe 1 ft. long and had them cut the ends and swedge them down to a bullnose; cut the pipe in half, weld it together. put a nipple in the top and in the bottom. We tested them at 90 lb. cold water pressure, and this fellow didn't have a leak. Out of 12 there were five that didn't have leaks. There were three that had one or two small leaks. The rest were terrible. One had 75 leaks.

The fellow who won the first prize was very much pleased over it. In the fall he is coming back to take an advanced course in pipe welding, including overhead work.

There are probably six out of that class that I will never see again. They will never be welders and they have had their chance. I don't worry about them any more, but these others, if they go ahead with an

advanced course in the fall (another 15 lessons) I believe they will be pipe welders.

Discussion paper on "How to Organize and Operate an Industrial Welding School,"* by F. E. Rogers, Publicity Manager, Air Reduction Sales Co.

Chairman McCune: I would like to ask Mr. Rogers whether the standard specimens showing good and bad welds are recommended or in force in his school so that a welder can be shown a bad weld or a good weld.

Mr. Rogers: If the school is equipped with a testing machine I would recommend the welding of standard test specimens 2 in. wide and ½ in. thick. If a 50,000-lb. capacity machine is available it will be necessary to split the coupons in halves lengthwise before pulling, to avoid overloading. The tensile test is a very desirable way of testing welds. The bending test reveals a great deal, but if the welder can be shown that his welds have only 40 or 50 per cent weld tensile strength in terms of the base metal, and that he must work up to 75 and 80 per cent, and finally to 90 per cent or better, he has got something definite to work toward. However, I do feel that the bend test will serve very well for a great many of our schools, especially those that are devoted to pipe welding.

Mr. Thurston: Mr. Chairman, I should like to inject a remark. It seems to me that whether it be a company or organization selling welding equipment, or whether it be a company or organization which does not, both have the same problems in training men. Mr. Rogers says, "The welding school operated by a company selling welding equipment . . . the problem of determining fitness is not up to the school director." May I take exception to this statement because I think that the company and the school it conducts assume a great responsibility in the training of men, not only for their own reputation but for the reputation of the men and their customers' good will afterward.

Mr. Rogers: The statement, Mr. Thurston, is in reference to a school of class No. 4, which is made up of men furnished by concerns, some of them perhaps 500 miles away. They are not likely to send any man to that school who is not dependable, who has not the ability to learn and who has not a genuine interest in what he is to be taught. It may happen, of course, that men might be unwisely selected and the director of the school would find that he would never make a good welder, but I assume in this paper that those men are not sent at company expense to be trained as welders; they are simply going through the welding course in order to understand what welding is, how the apparatus should be handled and what constitutes a good weld, what the causes of poor welds are. In other words, these men, as a rule, will be executives, foremen or supervisors of welding, or having welding operations under their control. A man may be a thoroughly competent foreman to direct

*Paper published in April, 1929, issue of Journal of A. W. S.

a group of machinists in a machine shop on lathe and grinding work, and be unable to go up to a grinding machine and turn out a job one-half as good as the poorest grinding operator. But he has the executive ability; he knows what he wants and how to get it. So it is, I think, with the type of school that I have in mind. It functions to train men for executive positions.

Discussion papers on "Organization and Management of an Industrial Welding School,"* by F. E. Sellman, Consulting Engineer, Servel, Inc., and "Organizing and Operating an Industrial Welding School," by R. B. Lincoln, Westinghouse Electric & Mfg. Co.**

Mr. Abraham: What kind of metal is used in the construction referred to.

Mr. Sellman: Seamless steel tube throughout except the flues that are made of ascaloy, but the machine itself or the unit proper is all seamless steel tubing.

Mr. J. W. Owens, Newport News Shipbuilding & Drydock Co.: This morning's session has been a very interesting and constructive one. Those of us who have been in the game for a number of years realize that the problem of training and qualifying welders is one on which the ultimate success of welding depends. The society has already accomplished much toward the development of a standardized training program, but has, as yet, been unable to assist in any scheme for qualification of the welder. Should a committee be appointed by the society for this purpose it will face a difficult problem as a satisfactory solution is not, as yet, in sight. Courses of instruction must of necessity cover the various welding processes and be adapted to the needs of many industries. While the qualification requirements for some industries for example ship construction and building construction might be grouped, yet the requirements for other industries, for example, aircraft construction and the manufacture of refrigerator units, are so radically different that there must be definite requirements for each one.

You have heard this morning of a course of training involving 15 lessons. Such courses might be satisfactory for certain classes of work. However, in ship construction we feel it requires a course of approximately 250 hours or about 80 three-hour lessons to produce a welder capable of consistently securing sound welds in the flat, vertical and overhead positions on our diversified work. The students are given evening courses on their own time from 4 to 7 o'clock. There are two classes of 12 students each attending the school every other evening. Every man in the school is provided with a welding machine and furnished free of charge with the necessary plate material, electrodes and current. On completion of the course each student is required to make a single V butt weld in a $\frac{3}{8}$-in. test plate 18 in. long, 6 in. being welded in the flat position, 6 in. in the vertical posi-

*Paper published in June, 1929, issue of Journal of A.W.S.
**Paper published in June, 1929, issue of Journal of A.W.S.

tion and 6 in. in the overhead position. A 2-in. specimen is cut from the center of the weld made in each position and the reinforcement ground off. To date 107 welders have been trained and tested and the average ultimate strength for their welds in all positions has been 60,000 lb. Our requirements are so high that it is almost impossible for a welder not trained in the yard to secure a position. Furthermore, we have found from experience that welders trained in our school are much more satisfactory.

Reference has been made to the training of men for industrial concerns at a welding school. The course that such students should receive would depend upon the student's qualifications and what is expected of him on completion of the course. The supervisors in our welding department were selected because of their general executive ability. However, we found that many of them were handicapped because they personally lacked the ability to duplicate the results obtained by the students. Everyone of these supervisors have, therefore, been required to take the welding course and pass the same test as required for the practical welder. As a result of this the morale of our welding department has been decidedly raised for the supervisor can now actually show the welder on the job how to undertake unusual and difficult welding operations. The welders graduating from our training course are not given a first-class rate on their graduation for we do not feel that they are first-class men although able to make welds having physical characteristics of a high order. The reason for this is that they lack experience which can only be acquired over a period of years and that during this period they require competent supervision.

The question of testing welds is an important one. In our school we have equipped a hydraulic jack with a direct reading gage for testing the students' exercise welds. This introduces a competitive feature among the welders which is very valuable. Of course we use the standard tensile testing machine for the final qualifications of our welders.

The hydraulic jack is also used for the testing of plug welds, for although such a weld might look to be very easy to make, nevertheless experience has shown that it requires a considerable amount of training. The test is made by punching the metal out of the hole and observing the percentage of fusion obtained on the sides of the hole. The school is also used during the daytime for the training of chippers and caulkers and training welders on specific jobs as they may arise. When such jobs present peculiar difficulties the welders assigned to the job are required to master it before undertaking it on a production basis. From what I have said it can be seen that our school is an asset not only from the standpoint of training welders but for the building up of a strong organization.

We do not give a certificate on the completion of the course. This has been considered on several occasions, but every time has been rejected for managerial reasons.

Mr. H. S. Card, Welding Engineer: Gentlemen, I have been interested in this subject of training operators for quite a number of years. When our publications were first started we immediately began thinking about it. Then some seven or eight years ago, in the course of a discussion, some remarks were made to the effect that the inability to secure good welders was a handicap to the progress of welding. So about that time we started quite a detailed investigation of all the welding schools and all the methods of instructions we could find. There was enormous amount of work involved in it. There were very few trade schools who were giving anything like respectable instruction, and there were a lot of them all over the country who were making believe they were teaching men how to weld, but the line-up of their instruction was pitiful.

We have induced our friends in the industry in all parts of the country to step in, in different places here and there and lend a hand to raise the standards of instruction. Consequently recent years have seen a tremendous improvement in the instruction in a number of schools and also a considerable elimination of the instruction courses which I would classify as pitiful. It has been an interesting study and we are continuing it. In fact, we maintain as far as possible a list of the good welding schools. It is very difficult to do that lately because there are so many new ones springing up.

We have corresponded with those schools. We have invited them to send their instruction programs so that we could compare them with others of the same type and make suggestions to them. We have made them special rates on our publications to get the students to read them if they wanted to. The service that we would give them in connection with their instruction has always been gratis, regardless of whether they were large customers or not, our theory being that the better welding we can get done, the more welding will be done.

Some remarks were made about the matter of giving a man a chance as he came out of a trade school. That is a very sound idea as far as the employer is concerned. I have had a chance to notice the progress of two or three men who have come to Chicago, graduates from schools with which I was acquainted personally and have placed them in various large organizations with a large welding force, telling the employer in each case that this man has not had experience, but he has the training. "I wish you would give him a chance and let me know how he comes out" In every instance of that kind the experience has been identical. The man's first weld was not taken very seriously by the employer, but in every one of those cases that first weld when tested proved to be strong and in every case that I have been able to check up on the men are still on the jobs and are regarded as among the best welders those employers have. These men knew how to make a sound weld and had been trained to make a sound weld first. When put right alongside of experienced men their work didn't look so pretty, but the experienced men were making good looking work and slighting the soundness of it. A man in that position simply had to be given a chance to acquire practice so that his work

would *look* as good as the other, as well as *being good*. If we can get trade schools to teach the process right and then get employers to give men who have been taught correctly a good chance, we will have a good deal better welding done everywhere.

In the matter of actual instruction we can't place too much emphasis on a point brought out by Mr. Rogers of teaching students to analyze the defects of their own work. Let a man find out what welding really is. Then let him do a job and criticise it himself. A man doesn't know how to weld unless he can tell a good weld from a poor one and why the poor one is poor. If more time is given to that and some of the refinements, some of the frills, if you please, left out, you will have men turned out with a sounder working knowledge of what is required.

The subject of the length of time required to teach a man is one of the best subjects you can pick for a long drawn out argument, because every man has a different idea and different conditions. Perfectly satisfactory welds for certain factory operations can be mastered by an ordinary workman in a very short time, but those men after mastering one welding operation are not welders by any manner of means. The sad part of it is, however, that those men go on the payroll as welders and don't know the difference themselves. After being laid off they apply to a different concern doing a different type of work and say, "Well, I have been on so and so's payroll for three or four years (as the case may be) as a welder." We are getting away from that as the management in different plants gets to learn more about it, more about the process and the value of having it under intelligent supervision. When they realize that welding is a process that requires some care and put somebody with good engineering ability in charge of the operations to supervise it, and take the pains to have that man thoroughly posted in the operation, the big problem of the human element becomes a pretty small problem. In fact, it becomes no problem at all.

There is one suggestion I would like to make regarding this meeting. In my estimation it is a very important and constructive session and I think it would be a mighty fine plan for the Society to arrange to print the proceedings of this meeting separately and see that the text gets into the hands of as many welding instructors in all parts of the country as can be found. There is a great deal of valuable suggestions here to instructors and I am sure they will use a good deal of it.

We can't compare the instruction given in the trade school with the instruction given in a manufacturing plant, and I think that when we are making recommendations about how to train welders we should bear this in mind: The trade school can only teach a man the fundamentals of welding. The manufacturing plant is anxious to get the man to work on a certain type of production and is going to teach him as rapidly as possible to get to work. It is a question for each individual plant to solve as to what percentage of the training in that plant is to be devoted to fundamentals and what percentage to the actual practice on the typical production work.

There was another point in Mr. Rogers' paper that was very interesting to me because I recently saw an example of how nicely it works out. He spoke of the care of equipment and the importance of teaching men to set it up properly. I visited a naval welders' training school two or three times. Most of the work is done on tubing of the same size that is used in airplane work. Incidentally, I saw the other day some samples of work of students which had been sent out. A friend of mine had requested them to send some samples to see what airplane joints looked like. Just a little while before that I had visited the Aircraft Show at the Coliseum in Chicago, where a number of different types of planes were exhibited. A good many of them were exhibited in such shape that it was possible to climb around in some way and find out how good the welding was. In my judgment the work of the students at that school seemed to be fully equal to the average work which was done on the planes on exhibition.

I would say from that that men who are trained by a good man in the fundamentals are quite apt to be efficient welders on production work in a factory provided they are given a chance to get started properly. I know that is a big problem in the mattter of pipe welding which has been brought up. It was brought up at a meeting of our Chicago Section just a short time ago—the length of time that it takes to teach pipe welders. However you can't expect a big steam fitting contractor to make a contract to weld all the piping in a big house or apartment building or office building and put all of the work in the hands of men who haven't had any experience. A tremendous amount of welding could be done by men who have never been on a job before, by men who have been trained in school. A lot of it could be done with good satisfaction. But, on the other hand, there would be a whole lot of work on the same job which would require expert men. So on big pipe welding jobs you must have various grades of men; you need experts there in charge to see that the fussy job is done correctly and to see that all of the second-rate men are doing at least as good as they ought to.

That point of view, I think, is one that you should take when you consider putting inexperienced men to work. Your men have got to get experience somewhere and you can always work them in and give them their experience on less important jobs in large organizations. If you have honest men, trained properly in the fundamentals, I don't think you will have very much trouble in bringing them along to become what you would call experts.

There is just one more point that I would like to suggest in the matter of training and that is every place where we have an opportunity to make recommendations on teaching a lot of emphasis should be placed on review. The instructor should check up on his own work through reviews to find out how much his men are learning. The responsibility is not all on the shoulders of the men. Some of it is on the shoulders of the instructor and it is up to him to find out as he goes along whether he is going too fast or too slow, and to make sure that his men are getting what he is trying to give to them. Otherwise the instruction is a failure.

WEDNESDAY AFTERNOON

F. M. Farmer, presiding.

Chairman F. M. Farmer, Electrical Testing Labs.: The first paper this afternoon, gentlemen, is one that deals with an old and familiar friend, the testing of welds. Some of us may have thought, in view of the extent of the test data on welds in our welding literature, that there wasn't much more to be said about tests of welds and particularly of butt joints, but I don't believe that is quite so.

The first paper is by Mr. Lobo of the Westinghouse Electric Manufacturing Company and deals with an investigation of butt welds.

Discussion paper on "Strength of Butt Welds"* by G. Lobo.

President Llewellyn: I would like to inquire of Mr. Lobo with regard to the fatigue tests. What number of cycles corresponded with the values that he showed us?

Mr. G. Lobo: We used 20,000,000 cycles before we decided that the welded joint had reached its endurance.

Mr. C. M. Hendry, Supt., E. L. Phillips & Co.: In regard to Fig. 14, I would like to inquire where the economic part comes in. I see no reason why the particular cross-section was taken; I see no reason why the two butts couldn't have been brought up closer if the object were to save metal.

Mr. Lobo: We made this distance the same as the thickness of the plate. If we made it any smaller we found that it was impossible to get good fusion at the start if we welded it at one time, and it was difficult for the welder to get his electrode in at the required angle. We found that even with this distance the same as the thickness of the plate the best the operator could do was to get the electrode in at somewhat less than 45 deg. to play on the edge and if it was made any smaller I feel that the fusion would be very poor.

Mr. J. J. Crowe, Air Reduction Sales Co.: I would like to ask Mr. Lobo if the increase in strength that he gets with the single V weld isn't somewhat offset by the fact that you are very likely to get the notch effect as a result of not getting thorough penetration.

Mr. Lobo: I can't answer that question entirely because in our joints we backed up the notch. In cases where that isn't possible I am not quite ready to answer it.

Mr. Crowe: Another question. I notice that the modulus of elasticity changed with the shape of the joint. Is that the actual modulus of elasticity or just some apparent modulus?

Mr. Lobo: In the case of the curves that I showed it is the measure of modulus. We call it that. The modulus can't change, but if you figure the modulus on the basis of the average cross-section of the test piece and the load, the total load, why then we found that it varied, but the point was that actually we had a different stress in one part of the test piece than in another part of the test piece.

*Paper published in April, 1929, issue of Journal of A. W. S.

Mr. Crowe: Internal stresses?

Mr. Lobo: Either due to non-uniform loading or to internal stresses, but mostly due to non-uniform loading.

Mr. Crowe: The third question I would like to ask Mr. Lobo—we have noticed very often in making welds on a low tensile plate, a plate having a tensile strength of 50,000 or 55,000 lb. per square inch and using an alloy steel welding rod, where the break is outside of the weld in the parent metal, that we get higher tensile strengths when using short gage lengths, such as you have shown there, than the actual strength of the parent metal.

Mr. Lobo: I think we can explain that by saying that in measuring the ultimate strength of any plate, we take the original cross-section and the total load, divide the total load by the original cross-section and call that our ultimate strength. If we have a weld in here that weld has different tensile characteristics than the parent metal. The yield point is not so marked and it is not as ductile as the parent metal. So that it is actually stiffer than the parent metal. Now, due to this effect, the parent metal in the vicinity is prevented from contracting, so that the cross-section at the point of failure is greater than it would be if we didn't have the weld there.

Mr. Owens: While Mr. Lobo's analysis is excellent, yet there are some factors which have been overlooked and which might change the results if followed up. For instance, he shows the value of the butt weld for various thicknesses of material. If Mr. Lobo did not increase the width of the section proportionately to the increase in thickness the section tested would gradually approach a square section and I know that this is likely to influence the results. Another factor to be considered in applying these tests to practical welding work is the introduction of greater thermal stresses in the joint because of the additional amount of metal deposited when the 45-deg. bevel is used as against the 30-deg. bevel. This alone might overbalance any apparent slight increase in ultimate strength obtained with the 45-deg. bevel. Taking all in all it is believed that the present 30-deg. bevel, that is, a total opening of 60 deg. for the weld, now generally used by industry, is satisfactory. Again, as a slight reinforcement of the weld insures 100 per cent strength of the joint this is all that can be asked. Where it is not possible to reinforce the weld the use of a 45-deg. bevel might be practically considered.

Mr. Lobo: Mr. Owens, I know you have made a good many tests on the residual stresses and I would like to ask if you actually made any tests on the internal stresses in the 45-deg. joint as compared with the 30-deg. joint.

Mr. Owens: I have not, but my experience indicates that the thermal stresses are proportional to the heat used. The more heat that is used the greater will be the base metal area on each side of the joint that will be heated and the higher its temperature. Therefore, the more metal deposited the greater will be the thermal stresses.

Mr. Lobo: I feel that the stresses are mainly due to the last weld

put in. The metal on each side of the joint will be heated to a certain extent and I guess it is correct to say that it will be heated more with the greater angle. However, you have a greater area across when you lay in the last bead, which can take up that shrinkage which must occur when the metal cools, in the case of a 45-deg. bead than in the case of a 30-deg. bead.

I am not saying that one is any better than the other, but I am saying that we should make tests on the question before we reach any conclusion. In the case of these tests here there were no such thing as residual stresses existing to any extent, because they were free to move on either side. In such cases I don't believe 45 deg. is stronger than the 30 deg.

Mr. Owens: While your tests indicate that very valuable information has been secured, neverthless I do not feel that the increased efficiency obtained with a 45-deg. bevel is enough to justify its general adoption in practice.

Mr. Lobo: Of course I brought out in the end that it is not always justifiable to go to the 45, but I do feel if you want to be sure we have the best joint we can make, we should go to the 45 deg.

Mr. L. J. Larson, A. O. Smith Corp.: I would like to ask if any of these were annealed or if they were tested just as they were welded.

Mr. Lobo: All these joints were tested as welded. There was no heat treatment given to them either before or after.

Mr. Larson: In that case wouldn't it be true that even though the specimen is cut relatively narrow, there must be considerable stress left in the weld and in the stock, due to the shrinkage of the weld on the top layers after the lower layers have been solidified? You get a tendency for the cold specimen to bend and that is more true on the thick stock than the thin stock

Mr. Lobo: The bending was not resisted in any way so that the plates did bend up and thereby relieve most of the stresses. In case there were any stresses, they would be greater in the thick specimens than in the thin specimens, and as the tests showed that the thick specimens were stronger than the thin specimens, I don't believe that would enter into the question at all.

Mr. Larson: Another point. I wonder if in the thick specimen you don't get a heat treatment due to depositing one layer on another which is less pronounced in the thin stock.

Mr. Lobo: If you do, you get fewer residual stresses.

Mr. Larson: That doesn't mean fewer stresses but you get a better microscopic structure.

Mr. Lobo: I don't think so, because the last joint in any case, the outside, would be the same whether it is thin or whether it is thick, and the failure will start in a weak structure anyway on the outside and progress inward. So that I don't believe that we can give any added strength to that factor. I may be wrong but that is my opinion.

Mr. Larson: One other question. Did you determine the ultimate elongation in these welds after failure?

Mr. Lobo: No. We didn't do that because it is very hard to get. If we take the elongation across there, it is a very small distance and we can't measure it with any accuracy.

Mr. Owens: The point raised by the last speaker of relieving residual stress by heat treatment should be considered on these tests. While it would not be necessary to consider heat treatment for all angles of bevel and thickness of material used in the test, nevertheless its effect on the results should be taken into consideration. The specimens tested might be heated to 1150 deg. Fahr. The other factor which has previously been mentioned and which should be considered is the ratio of width to thickness of specimen, this should be kept constant. The shape of the tension test specimen adopted by Mr. Lobo wherein the stress is concentrated in the weld is excellent and should be adopted as a standard.

Mr. Lobo: As far as the heat treating goes, I can say that tests are now in progress in which specimens are heated to different temperatures so that we will be able to settle the question before the next meeting of the Welding Society. It becomes rather difficult with testing equipment available to keep the ratios of thickness to width the same.

Mr. Owens: I fully appreciate your problem. I am only requesting that final conclusions be not drawn from these tests until the factors I mentioned are given proper consideration.

Mr. H. A. Anderson, Bell Telephone Labs.: I think that Mr. Lobo has enough material to give us some curves showing the relationship between strength of weld and ratio of width of the specimen to thickness of the plate material for the test specimen.

He has spoken about the limitation on the width of specimens as related to the capacity of the testing machine. We have had occasion to test some specimens of joints in ⅜-in. plate material in ½-in. wide specimens, and 1½-in. wide specimens, and there appears to be quite a decided difference in the results. This is indicated by Mr. Lobo's table in which he shows a value of ultimate strength of 56,000 on page 57 for the ½-in. wide and only 47,000 for corresponding 3-in. wide specimens.

It would be highly desirable if he could show some tables from his studies so that we could estimate the strength for a standard width of specimen from the results obtained on a type of specimen which is within the capacity of our testing machine. It would seem logical, also, for him to tie in his data on his proposed constricted width specimen with the corresponding strengths on the American Bureau of Welding standard specimen.

Similar information should be given to show the effect of changes in the free length of the specimen between the jaws. This seems to determine, in many instances, whether the specimen is going to break in

the weld or in the parent metal. I would like to see this added to the valuable information that is given in the paper.

Chairman Farmer: If I remember correctly, I didn't notice a record of the number of tests which are involved in each of your averages. Am I correct in that?

Mr. Lobo: I stated that there were a total of 112 tests made in the large table.

Chairman Farmer: Perhaps the information is there but the general point I would like to make is that in a record of this sort it is always pretty important in the final conclusion to know the number of tests which are involved in a given average or a given point on a curve so that we can know how much weight to give to it. It is better yet to give all of the individual results so that we can determine the average deviation from the mean.

Mr. C. D. Jensen, Lehigh University: The structural engineer is always interested in the modulus of elasticity and in the proportional limit. I notice in comparing these values of Mr. Lobo's with those given by Dustin, a Belgian professor, in a paper which came out about a year ago, that the modulus of elasticity compares very favorably if one considers in Mr. Lobo's paper only the good specimens—those that develop say 50,000 lb. per square inch. I think possibly that one ought to discount the modulus for the poorer specimens because in measuring the modulus of elasticity on a weld which is imperfect, there must be some variations in stress, some slipping and other things of that nature going on internally which upset the regular elongation of the weld metal.

The proportional limit does not agree as well with that given in Professor Dustin's paper as the structural engineer would like to have it agree. However, two entirely different kinds of welding rods were used in the two investigations, which may account for the difference. I think it highly important that the proportional limit or else the yield point be established for the weld metal of many different welding wires. If important differences are discovered, the welding wire specifications, especially for structural work, should be amended to include a minimum value for the proportional limit or yield point of the weld metal as found by some definite test procedure.

Mr. Lobo: I would like to answer that last point first. We were treating here a study of the variables of the angle, thickness and the single and double V, and I felt that the study of the probable minimum or the absolute minimum was out of place in this paper. It is a very interesting study but one that requires a great deal of time.

As far as modulus of elasticity is concerned, I think that the point that was brought out is very good. If we stated that the modulus of elasticity of the welded material is always the same, then if we find the modulus of elasticity to be lower, we can assume there were some places where we didn't get weld metal and that there were irregularities that lowered the modulus of elasticity and brought it down below the value we would expect.

Mr. R. M. Allen, American Car & Foundry Co.: I would like to ask Mr. Lobo if, in the determination of the failures on the straight-sided test specimens which failed outside of the weld, the failures represented a failure at a lower value than that of the parent metal itself. It strikes me that if such were the case, there is an indication that the weld itself might affect the strength of the metal outside of the weld. I bring this up because in my own experience the failures that I have seen from welds frequently occur outside of the weld. The study, even when it is confined as Mr. Lobo just mentioned, to variations in the angle and the single and double V, should still take into account the effect of all of these types of welds on the nature of the parent metal each side.

Mr. Lobo: We found in almost every case that where the failure did occur outside of the weld it occurred at a higher stress than we got from making tests in the parent metal without any welds. I think that I brought this out to some extent before when I said that this was due to the fact that the weld prevented the parent metal from contracting and necking down. It is difficult to state that the presence of the weld affects the strength of the parent metal in the vicinity of the weld, although from other tests that I didn't report here I feel that it doesn't affect it to any great extent, because we have had failure occurring 4 or 6 or 8 in. away from the welded joint at values expected from the particular steel we were using.

I feel that the microscopic structure is affected by the heat of the welding, but due to the stiffness of the welded joint making the effective section greater, we will find that it doesn't weaken it enough to cause failure near the weld.

Mr. A. M. Candy, Westinghouse Elec. & Mfg. Co.: I find that we are all inclined to hunt for additional variables in our testing work and I am just a little bit surprised to find that Mr. Owens overlooked one that happened to pop into my mind as I was sitting here looking over this paper and that is the question under Item No. 1 on page 53 of Mr. Lobo's paper giving the variation for the parent metal. He omits the question of temperature of the parent metal. It seems to me there is a possibility for those who are considering welding structures out of doors to be interested in the initial temperature of the plate which is worked on. We might carry out a series of such tests starting with the various initial temperatures of plate material. That might work around to the point where we might supply each operator with a pyrometer that he could carry along with him and not try to exceed certain temperatures.

Getting down to the bottom of some of these question which are under dispute I believe that tests of this order will have to be carried out with automatic welding equipment to eliminate the human equation. Some conclusions which might be drawn which only vary 10 or 15 per cent from each other may very readily be due to the operator. Even though the same man welds all specimens, his temperament varies from day to day and the results vary accordingly. I think that is evidenced by the figures given on page 54 of Mr. Lobo's paper,

where we find the beveled joint as shown by No. 3 (which is certainly a highly undesirable type of joint), showing even greater strength than No. 4, for example, which, to my mind, should be very much easier to weld. It looks to me that the operator in making No. 3 had exerted himself a great-deal more than he must have when making No. 4 in order to get a result anywhere near as good as he did. For that reason I think such tests should be checked by automatic welding as well as by hand welding if we are going to get down to the basic facts.

Mr. Hobart: Mr. Lobo spoke of having the plan of making some heat treatment tests that will be published later. I wonder if he would at this time be prepared to state in a general way the nature of the program he will be following.

Mr. Lobo: We have chosen only one type of joint for these tests as we don't want to complicate them any more than necessary and we are taking a 45-deg. single V and welding up plates of different lengths and making them all ½-in. thickness. Then we are heat treating these to five different temperatures which are 400 deg., 1000, 1550 and 1700 deg. Fahr. After heat treating we will make tensile test pieces and fatigue test pieces and impact test pieces, and they will all be exactly similar at different temperatures. After we have finished them we hope to be able to compare them at the different temperatures. That is a program which is now under way and that is all we have planned for immediate work. There will be more later when we get this finished.

Mr. M. Male, Massachusetts Institute of Technology: Would it be apropos at this time to introduce a pictorial representation of the actual conditions that exist within a welded bar? I have in the last two months, in connection with certain work I have undertaken to perform for the Structural Committee of the American Welding Society, done some photo-elastic work in the laboratories at M. I. T., and though the discussion has at present concerned butt welds, the specimens I have are those of fillet welds. I have brought down with me two or three slides that show pictorially and accurately the actual conditions that exist within the body of the welded pieces. If it would be of interest I would be glad to exhibit them.

This picture that you see here on the screen (Fig. 1) is being shown for the first time. It is an actual picture of what occurs in the body of a celluloid model of the joint in question. The large bar that you see on the right, bar "A," is the main bar. This other bar that extends from the left, bar "B," is the strap that joins the two bars that are gripped within the jaws of the testing machine. The dark rectangular areas shown on both sides of the strap are the fillet welds themselves.

Mr. Lobo's discussion mentioned something about the desirability of avoiding undue concentrations of stress. The picture, I think, shows fairly clearly what happens. The stress lines in the body of the bar at some considerable distance back are fairly uniform. As the stress lines approach the strap they must change their direction from a hori-

zontal one into an inclined direction to pass through the fillet and then transfer into the strap and get out the same way. The black areas in the centers of both bars are regions of zero stress where the stress lines, to get into the fillet and into the other bar, have skirted this area and come down through and got into this bar. It is rather difficult to show, but I think you can see that more or less in this area furthest from the fillets the color is uniform. The two fillets here shown are the regions where the stress concentration is very high.

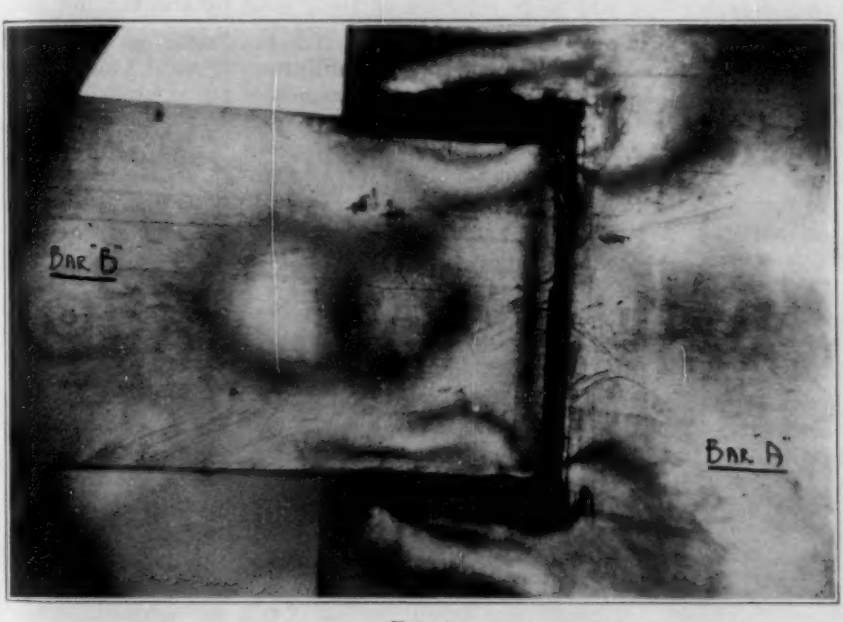

FIG. 1

It was obvious from an inspection of the results and from a measurement of the stresses existing in this particular specimen that the intensity of stress at this particular section, which measured the highest, was twice that of the uniform stress some distance back in the body of the bar.

The peculiar impression that the stress lines show here is due to the fact that in pulling the tensile specimen itself there was a tendency for this piece to bow in and what you see here as a little dark area is a very high concentration of compression instead of tension. The area surrounding it is a tensile area. This concentration is a compression area. The piece of steel, if tested in a testing machine, would not fail in the fillet, as it was intended to fail, but due to the fact that the load taken by the cross-sectional area of this bar was small compared with the load that the 2-in. fillet could take, the bar would rip out along the lines shown by the stress lines.

This slide (not illustrated here) is an enlargement of the corner of the previous slide shown where the entire area shown here (Bar A—

left, upper and lower ends of bar) is considerably dark, showing that there is no stress existing in this part of the model at all, and insofar as any effects on the test were concerned it might just as well have been cut out for every particle of stress that was in the main body was transferred into the smaller strap before it got into this area.

The obvious results from a study of the stress determination and from the pictures show that the bars themselves had to be proportioned to stand as much load as the fillets could take before the latter became overstressed and were relieved of their load by the tearing out of the bar itself.

The third slide shows a very slightly different type of test specimen (not illustrated here). These two bars are of equal cross-section and they are overlapped to the extent of 2 in. as called for in the specifications, the weld being a band weld along the edges of the specimen, the area shown here being the weld itself. (Specimen 6821.) You can see fairly conclusively, I think, just what the effects of the stress concentrations would be on a model of this sort. The tendency would be, if the slightest bit of eccentricity were present in a joint such as this, to rip out the corner immediately adjacent to the fillet and that the fillet instead of taking a uniform load along its length would be ripped off and sheared completely across.

This particular model failed at a load 11 per cent that of the other model, though the cross-sectional areas of the two pieces were exactly the same. That, I think, shows in some measure (and it is authentic, gentlemen) just exactly what happens inside the body of the joints when they are subjected to a pull. The concentrations of stress show up. The intensities range from the yellow to the red to the blue, getting not quite into the second order and if the particular joint were so constructed as to take a higher load, another distinct order of color would appear, each particular order representing a different stress intensity. It isn't very often that one can see actually what happens inside and I thought perhaps it might be of general interest to the gentlemen of the society to introduce those now.

Chairman Farmer: This is a most interesting contribution by Mr. Male of the Massachusetts Institute of Technology. I wonder if Mr. Male wouldn't just like to say a word as to how these models are made and how the pictures were taken because some of us may have forgotten about the development of this method of studying internal stresses with celluloid models by Professor Coker of England a few years ago.

Mr. Male: Instead of using steel for the models, we at the laboratory have used celluloid which possesses among other things, the three properties that render its behavior under load the same as the behavior of steel. In other words, it follows the natural laws of equilibrium, it will exhibit small deformations under great loads, it will obey Hooke's law until the elastic limit, and it is a homogeneous material throughout; so that in any calculation or in any determination of stress the modulus of elasticity of the material passes out and one only needs to deal with the stress itself in the body.

We took for purposes of comparison a model, Specimen 2122, which conformed exactly to the specifications laid down by the structural welding committee and I think I may represent the model as follows: Looking at it in plan, these bars being 14 in. long, it was possible to grip them in the jaws of the testing machine near the ends so that the stress distribution, by the time it had reached the body of the bar, was quite uniform throughout its entire width. The job that we had with this particular type of joint was the joining of these two bars together in such a manner that the conditions would more or less conform to those that actually existed when two bars or three bars of steel of that type were welded together.

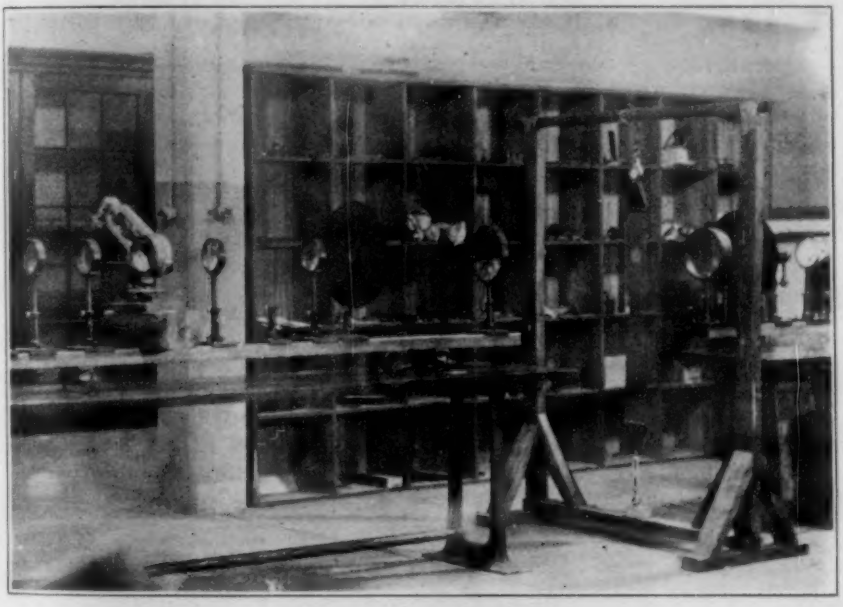

FIG. 2

We cut out from the same material that the celluloid sheets were made of, triangular fillets of the dimensions laid down by the committee and glued them to the two bars with a solution of celluloid in a suitable solvent to make them stick. We tried particularly to see that we more or less got identical conditions. To do that we were fairly careful to see that when we glued those bars together we allowed enough leeway between or enough clearance between the two models so that some of the sticking solution would escape for perhaps ⅛ of an inch underneath the body of the strap. We tried in that way to more or less conform to the condition that if you got penetration or fusion in the steel itself you would get perhaps that much anyhow.

Then we set the model up in a loading machine and we took a load of about 400 lb., I think, to start with, which we weren't at all certain it would carry, and when it held the 400 lb. we increased it to 500 lb.

The property of celluloid in allowing light to pass through it is not its only property. When circularly polarized light is sent through a suitable arrangement of lenses, nicol prisms and quarter wave length plates and is passed through the specimen in a vertical condition, as shown in Fig. 2, the light is broken up into two component rays at right angles, each particular ray vibrating along a line of principal stress. In any body under stress there are two lines of principal stress at right angles to each other and this circularly polarized light has the property, when passing through the model under stress of being broken up and made to vibrate along those two particular lines of stress. Then, passing the light through another series of lenses, quarter-wave length plate and nicol prism, we are enabled to throw the light on a screen, showing in colors the stresses produced by the loading.

The purpose of the quarter wave length plate and the nicol prism was, first, to make the light vibrate along a certain definite line in one plane only. The quarter wave length plate set up an interference effect by which we could get colors in the model and the second series cut out those that we did not want and only gave us those that we wanted to measure.

To measure the actual stresses in the model was fairly easy and it is accurate (if carefully done) to within 2 per cent of the load that we put on it.

In series with the particular model that we had, further along down in the series of the lenses, we put a comparometer which was more or less shaped according to the standard tensile specimens of the A. S. T. M., being a bar about six inches long, of approximately a tenth of an inch cross-section, a known load being applied on that by means of a dynamometer. The light from the model was made to pass through the comparometer and the superimposed light then allowed to fall on the screen.

When the tension in this comparometer was exactly equal to the tension at any particular point we wished to measure, the direction of this comparometer being at right angles to the direction of stress, then the net result was, well, blackness, there was no color there. By screwing up the dynamometer until we got a complete blacking out of all color, we could then record what the actual stress at any particular point in the model was.

We took a number of stress lines, 24 in number, followed them through as they went through the fillets and into the strap and then out the other end, and we computed, or measured rather, the stress in 148 points along the lines of stress. The measured stress, however, was not a principal stress; it was a difference of the stresses. If one of the stresses might be called a "P" stress and the other a "Q" stress, the stress that we obtained from the measurement of the load in a known cross-sectional area was a difference of the two stresses. It became then a problem of breaking up the difference of the stresses into each of its component stresses.

Fortunately, we were able to do that fairly easily. We knew that in a section away from the fillets where the stress was uniform there was no stress normal to the ege of the bar, and we knew that all of the stress was existing in one direction only. We then measured the stress. Since one of the stresses was equal to zero and the other stress had that particular measured value, then by means of a mathematical formula laid down by Professors Filon and Coker, of the University of London, it was possible then to integrate from one point to the other and come out with each individual value of the stresses.

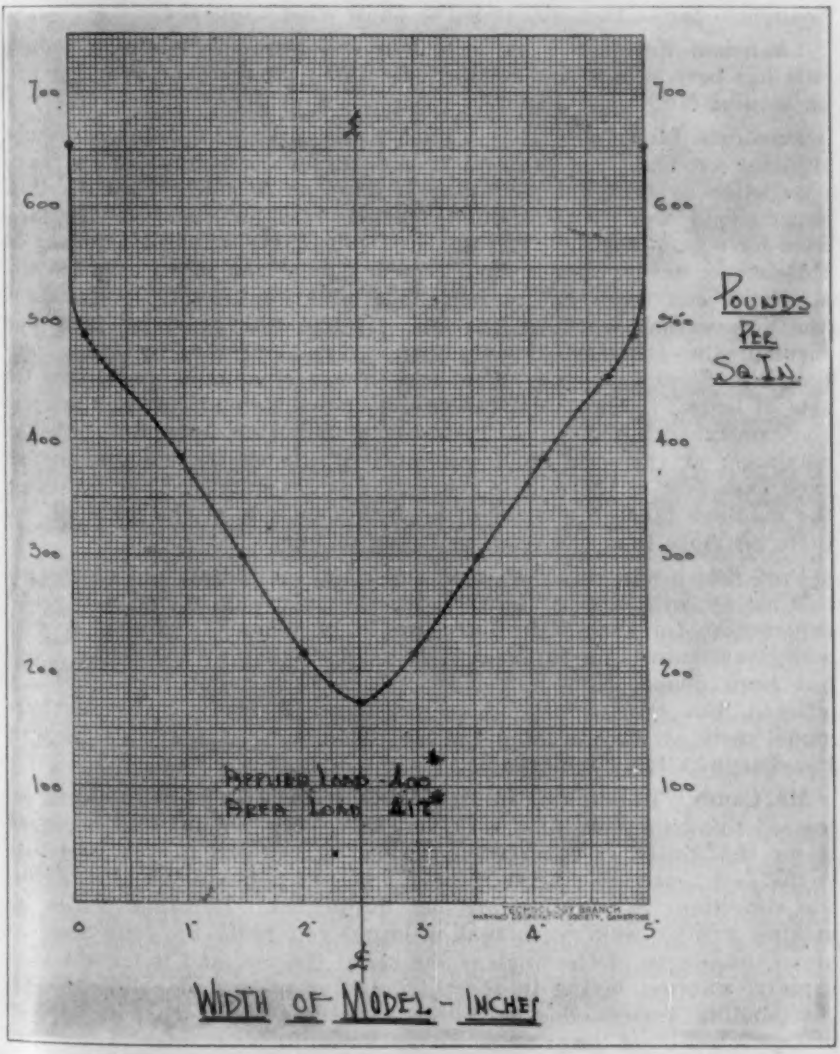

FIG. 2

As a check, we computed, along one section where the stress lines were inclined, and another section where the stress lines were all straight, the various stress intensities that were measured, and we plotted them into a curve, Fig. 3, the maximum stress being at the edge, of course, where the tangential stresses are usually a maximum. By means of a planimeter, the area underneath the curve was computed, and multiplying it by the thickness of the bar itself, we got a computed load of 412 pounds against a known load of 400 pounds, an error of three per cent, which, we felt, was fairly accurate for such experimental work. The other determination came quite as close as that, and we felt that the results we had were authoritative enough so far as they attempted to show what happened.

Chairman Farmer: I am sure you will agree with me in feeling this has been a most interesting diversion. Is there any further discussion of Mr. Lobo's paper?

President Llewellyn: It is a remarkable thing how different people, thinking on the same problem in different places, come to the same conclusion by different methods. It happens that while the M. I. T. experiments were with celluloid models, similar results with steel bars have been secured, and are still continuing at the University of Pittsburgh, except that instead of using polarized light, a special instrument was used that measured deformation. Prof. J. Hammond Smith has that work in charge. The specimens were furnished through the courtesy of our friend, Mr. Danforth, by the Jones-Laughlin Steel Company. Prof. Smith has completed up to date 12 sets of tests. Every one of the twelve shows a shear curve in general conformity with the M. I. T. stress distribution, extending from a maximum at the ends to a minimum at almost the middle, but in each case just at the middle there is a slight hump. That is to say, the readings taken a quarter of an inch each side of the middle are a little bit more than the reading at the middle.

Prof. Smith was here last week and I had the pleasure of discussing this matter with him. We concluded the only way to find a physical explanation for that little hump would be to make celluloid models and investigate them in exactly the manner that we have just heard has been done. How numerical values correspond I couldn't say offhand, but the correspondence in general results between these model tests at M. I. T. and the steel bar tests at the University of Pittsburgh is truly remarkable.

Mr. Candy: In listening to Mr. Male's description of celluloid model tests, I think they are fine work, but there is one point that occurred to me that probably occurred to several of the rest of you, and that is the fact that in laying in these fillets, to duplicate the fillet welds, the conditions of welding are not duplicated. In other words, in making a fillet weld by actual welding, you build up your stresses along the length of the fillet as the metal freezes, and it freezes very rapidly, whereas laying in these triangular prisms of celluloid with the binding cement doesn't build up stress along that length of prismatic celluloid the same as we do in welding.

If somebody could devise a way of getting a bond in celluloid in a manner simulating as closely as possible putting down the weld metal, maybe our stress concentrations would be even worse than indicated by the celluloid specimen.

Mr. Owens: In reply to Mr. Candy, I will say that a few years ago I tested some welded joints similar to that used in the celluloid model. In these specimens the base metal and not the weld failed, due to the stress distribution clearly shown in the celluloid model. I have such a sample in my office today. The method used to prevent shearing of the base metal was to lengthen the fillet welds parallel to the lines of stress.

THURSDAY MORNING
April 25th, 1929

The Third Technical Session convened at 10:00 a. m., Mr. F. T. Llewellyn presiding.

President Llewellyn: The first paper is by Mr. A. Vogel, of the General Electric Company on the "Design of Joints for Welded Steel Structures." Several of us have heard Mr. Vogel speak at previous meetings, and I am sure that we shall be very much interested.

Discussion Paper on "Design of Joints for Welded Steel Structures,"* by A. Vogel, General Electric Co.

Mr. A. Vogel: Mr. President and Gentlemen: The paper entitled "Design of Joints for Welded Steel Structures" has been published in the April Journal of the American Welding Society. In addition to the paper, you may be interested in the inspection, on April 23rd, of the welded steel structure of Building No. 1 of the West Philadelphia Works of the General Electric Company. This building is probably the largest welded structure built to date, as it contains approximately one thousand tons of steel, and is one hundred and forty feet wide by five hundred and fifty feet long. The building contains about twenty trusses of 80 ft. span, about twenty of 60 ft. span, and about seven of 75 ft. span. In addition, it includes crane runways of the usual bridge crane type, and also two crane runways of the wall type. The inspection was made for the purpose of discovering whether any defects had appeared after about one year's service, and also to be able to report to this meeting just how a welded steel structure stood up under service.

It is a pleasure to report that a very detailed inspection failed to disclose a single joint which showed any defects whatever. The building is in perfect condition. The cranes have been frequently loaded to maximum capacity, and there has been no criticism whatever regarding any part of the building frame. There is no hesitation, therefore, in recommending welding for industrial buildings where cranes of various types are used.

*Paper published in April, 1929, issue of Journal of A. W. S.

In preparation for some of the tests reported in the paper, interesting studies were made. For the benefit of those who have not heard of these studies, they are presented at this time. A series of rubber specimens, imitating specimens used for testing metal arc welds, were made, with lines drawn on the specimens with India ink. The rubber specimens were "welded" to a base plate of rubber with glue along the edges imitating welds. Five typical connections were made. The specimens were then stretched in order to observe distortion produced by tension. In three of the specimens the welds were placed symmetrically with the center line of the specimen, and the center lines of the specimen remained straight lines after application of tension. Two of the specimens, however, were "welded" non-symmetrically, and curved center lines indicated that additional stresses were set up in the specimens due to non-symmetry of the connections.

Another interesting study was the use of a rubber model of plates in tension with the connections made by placing five rivets in a row. It will be of interest to know that when the specimen was placed in tension, the outer rivets were firmly held, the rivets between the outer rivets and the center rivet were lightly held, and the center rivet could be removed without effort. Apparently all rivets did not take their share of the load, the outer rivets taking most of the load, the center rivet taking no load, and the rivets between the center and outer rivets taking probably one-half the load the outer rivets take. Of course, a rubber model test cannot be quantitative, but it may be indicative of what is going on in a group of rivets. A model is available and will be passed around so that all interested may examine it.

President Llewellyn: We are very much indebted to Mr. Vogel for his illuminating, practical and detailed description of these structural methods. The meeting is now open for questions or suggestions which should preferably be restricted to the welding of structural steel.

Mr. Candy: Mr. Vogel is certainly to be congratulated upon this very thorough and interesting paper which he has presented here today. As I told him out in the hall a while ago, I consider that his paper (in the light of my limited experience with structural steel welding), is undoubtedly the best paper that has been presented to date on this subject. He has brought out a number of points which must be considered by the structural design engineer if his welded structures are to prove successful.

The question of designing trusses, for example, taking advantage of the fact that designs can be worked out whereby the center of gravity of the various members intersect at a point, is one which must not and cannot be overlooked by the designing engineer. As a matter of fact, welding in the structural field has produced certain by-products the same as it has in the field of constructing machinery by welding. In the latter field, the foundries have been given some competition. They have improved their methods, and in many cases we are getting castings considerably cheaper than in the past, and as a by-product of welding in structural steel work, we are getting a new school of

design in structural steel construction. If the designer is to produce successful designs, he must take into consideration all of the points which Mr. Vogel has raised.

I think Mr. Vogel is also to be congratulated on account of publishing the design tables which are certainly very useful, and show his broad spirit in making them public so that everybody can use them, instead of keeping them for himself only.

In the case of some connections, which Mr. Vogel has mentioned, there certainly is room for considerable further study. For example, take a beam to a column connection, the question of whether or not side angles should be used to connect a beam to the column or whether the bean can be connected to the column by weld metal directly, as to what effect the bending stresses are going to produce in the welded connection, has not been thoroughly demonstrated up to the present time.

In the case of truss construction, if the centers of gravity of the rafter—bottom cord and the column do not intersect at a point, eccentric secondary stresses result. If the designer is not careful he may overlook the fact that he has either got to make his gusset plate large enough to carry those stresses further back in the structure, where they will disappear, or some other expedient must be used in that particular connection.

Those points are quite frequently overlooked, and as a by-product again of welding, the designers are giving a great deal more thought today to their riveted structures than they ever did before. It has been pointed out by a good many people that we actually in a great many respects know more today about welded designs than has been known about riveted designs for the past forty years.

Those are just a few thoughts that I had in connection with Mr. Vogel's paper. We are all interested in the latest developments, so I brought along a few slides illustrating one of the largest projects which is being constructed for us at our Trafford City works in Trafford City, Pa. If we can have the slides, I will show you what is going on.

Incidentally, I might say that, as Mr. Vogel mentioned, we have gone entirely to welded buildings for our plants. At the present time we have a total of 13 buildings at our various plants which are being constructed by welding, and another building, the contract for which has just been let, and several more in the future.

The first one was the Sharon Building, and inspection of it at frequent intervals has shown all the welds are still intact, that building having been constructed in 1926. The bridge at Chicopee Falls, Mass., has been inspected regularly by the railroad companies and at intervals by a representative from our own company, and with the exception of the initial crack, which all of you heard about, no further trouble has developed in that bridge..

The building Fig. 1, is just now being completed, and is quite a

project in itself. We are calling it four buildings, due to the fact that there is a very decided difference in the various types of construction. The left hand structure is about 440 feet long by 62 feet wide. The right hand structure is 460 feet long by approximately

FIG. 1

100 feet wide, and this is about 133 by 60, giving 100,000 square feet of floor space in the building. There are various types of construction in the left hand structure, as you can see, a portion being three stories in height and the rest of it being single story construction.

To carry a steamline from the existing foundry plant over to this building, which is being erected, an overhead bridge construction was made, by welding, on columns at about 100 intervals, and this steam line, which is a standard 12-inch line with expansion loops in it, is entirely arc welded. It was an interesting thing to note that the only difficulty experienced with that line was at the connections at the ends of the loops, which were bell and spigot connections. All of the connections in the straight pipe were standard bevel construction with butt type joints, and none of those joints showed any leakage under test at 150 pounds pressure, but a few of the bell and spigot joints at the ends, where plug welds were made through holes into the inner end of the pipe, showed some leaks, but none of them were sufficiently serious that they couldn't be stopped by simply center-punching the hole. The entire line is 2250 feet long from its original source to the end in the building. The bridge construction is 1500 feet long.

There are a couple of questions I would like to ask Mr. Vogel before I close.

In the first place, in constructing one of the buildings at East Pittsburgh, the roof truss members were made by splitting Carnegie beams and the panel members were also made of T's coming in at the proper

points. The ends of these T's were split so that they would slip over the webs of the bottom chord and rafter T members. There has been some question as to whether that design is really necessary, or whether angles for the web members are satisfactory. I would like to have some light on that particular question.

There is one statement made by Mr. Vogel that I didn't quite understand; on page 72 Mr. Vogel says that "truss lines should intersect at a point and loads applied to the trusses should be applied at these points." That is evident, but the next sentence says, "The center of gravity of the truss members and the center of gravity of the welds applied at the points should coincide with the truss lines." The question of the center of gravity of the welds coinciding with the truss lines—I don't just see what Mr. Vogel means, and I would like to get a little more information.

Mr. Vogel: Mr. Candy's two questions will be answered in order.

We have not used the method of slotting T's described by Mr. Candy. At Bridgeport, Conn., where a similar design was used, either single or double angles were used for web members and these angles welded directly to the webs of large T's obtained by splitting Carnegie beams. The chord members were large T's and single angles were used for web members. In order to reduce cost, it was necessary to weld the single angle web members onto one side of the T-shaped chord. The web members however, were located alternately on either side of the webs of the chords. The vertical angles were placed on one side of the web of the chord, and the diagonal angles were placed on the other side. For the Bridgeport trusses it was considered that this method was as near to the correct theory of truss design as necessary and entirely satisfactory.

With respect to the second question regarding truss lines intersecting at a point and center of gravity of welds and truss members, etc., it was meant that the load should be applied vertically above the point of intersection of truss lines, that the center of gravity of chord and web members should coincide with truss lines, and that the center of gravity of all of the welds applied to any one member should also coincide with its own truss line.

President Llewellyn: Mr. Danforth's name was mentioned. Have you anything further to add, Mr. Danforth?

Mr. G. H. Danforth, Jones & Laughlin Steel Corp.: Mr. Chairman, after Mr. Candy's talk on North Trafford, about all I can say, as far as that job is concerned, is "thank you."

I think Mr. Vogel's paper most excellent. I don't know just what relation it has to a monograph that was put out by Dr. McKibben on the same Philadelphia job (its matter is more or less similar) but the two papers taken together form, to my mind, the best published material on structural welding that there is in the United States today. I have only handled three welding structural jobs, of which Mr. Candy mentioned two. Every job that has been handled has had its lesson.

I agree thoroughly with Mr. Vogel that there is no such thing as a standard welded structural detail. They are only in process of evolution. What form they will ultimately take, I do not know.

As I told one man, speaking about the larger North Trafford job, I had had to go back forty years in order to get a structural detail that was adaptable to welding, and it has worked very, very well.

One thing that is to be considered in a structural design is the matter of costs. You can spoil a structural design from the cost point of view quicker in details than any other way that I know of, and I think that on those details can be spent all the thought, all the brains, that all of us have. There are some things that it would be well to bear in mind. Both Mr. Candy and Mr. Vogel have touched on them. And that is the matter of using material as you get it. By that I mean use it on the job without or with a minimum amount of previous preparation. I don't like the idea of splitting a beam. It gives you a T, gentlemen, but when you split the beam you have got something you have got to straighten afterwards, and there is rarely a case, I would think, where you cannot use two angles just as well.

Take the matter of T's, we have had some pictures shown here where small T's are used. If there is anything in the entire catalog of every steel mill that is hard to get and on which there is no variation in section, it is T's. An angle answers the same purpose, better, more economically and is more readily obtained.

Take the matter of cutting, if you can take material with a cutting variation three-eighths plus or minus, you have got a decided advantage, and any money spent in getting exact cutting to my mind would be wasted, and you can't afford to waste it.

One trouble, I think, with a good many welded structural designs, as we have seen them, has been the fact that they have been designed by welding engineers instead of by structural men, and the result has been that welding has been applied as being the all-important point, rather than the fact that the structure itself is important and that the welding is only a means to an end.

Also in the matter of economy comes the question of amount of welding. Mr. Vogel has very properly pointed out that the welding should be carefully studied. Every additional inch that you add to a welded job means something like ten cents added to the cost of the structure, and in these days we can't afford to throw around many ten-cent pieces.

There is just one other thing that I would like to touch on, and that is rather to emphasize most thoroughly what Mr. Vogel has spoken of in eliminating bolts. We are all in the habit of using bolts for assembly purposes. We were all brought up on it. I guess that is the reason why we can't get away from it. But on that North Trafford job, I would like to say, there is not a main piece in there that has a hole in it, not one single solitary hole. The connections were so arranged that we were able to assemble even

that five-story portion of the building without using a single bolt. The connections were similar to what was shown by Mr Vogel, namely, shelf angles, but as a wind brace connection, the top flange of the girders all had a connection angle on them, which, by means of a C clamp, was able to hold the girder in place and eliminate bolts entirely.

I might add that the five-story portion there was made with the ordinary reduction in sizes of columns going up with the idea that it would probably be advisable to put up the building story by story. As it turned out, another method of attack was preferable, and the sections were all assembled, splices all welded up, and the columns for the entire five stories were picked up in one piece and stood on end. That got around a difficulty that had bothered us a good deal.

I think there is one other point I might mention in the design of welded details that we could all think about to advantage, and that is the shrinkage in the weld. I don't think any of us know what takes place when you weld up a connection with anywhere from a foot to two feet of welding on it. It seems obvious that that weld is going to shrink when it cools, and, like the little rubber sample Mr. Vogel has here, whether the middle rivet is going to remain loose or not time will only tell, but provision for shrinkage, I think, should be made, and on that basis it would probably be better to have two short welds, say something under a foot long, than to have one weld two feet long.

I think, Mr. President, that is about all I can add to this subject.

President Llewellyn: So far the discussion has been along the line of the form of material used and the shape and design of welds. There is another very important phase of this question, namely, the grade of material used. I notice that in the audience is present Mr. F. M. Speller, who is Chairman of a very important Committee of the American Society for Testing Materials which has been charged with the determination of suitable grades of material to be welded, not only for structural purposes, but for any purpose. Perhaps Mr. Speller may care to ask some question, or present his point of view to the meeting.

Mr. **F. N. Speller,** National Tube Co.: Mr. President and Gentlemen: I am glad to have the opportunity to bring up that question. While it may not be as important as design and workmanship, it undoubtedly is a factor at least in the economics of welding. The question of specifications has been put up to the A. S. T. M. Committee on Specifications for Steel for Welding. That Committee was originally organized to lay out specifications for forge welding, but we frequently found that electric welding interests were using A. S. T. M. specifications, although they were not originally intended for electric or acetylene welding. At the suggestion of the American Welding Society and others, the A. S. T. M. have assumed this responsibility, and the Committee on specifications for welding has been enlarged to include various interests, including three or four members

of the American Welding Society. We have one official representative of the A. W. S. who is charged with keeping us in touch with the work going on in the American Welding Society, and we will look to your Society to do the necessary research work.

We have had one meeting in Chicago last March which was very well attended. Of course, this was more of an organization meeting. One thing that struck me at that time was the lack of information as to the various grades and qualities of steel available for welding. The distinction between grade and quality wasn't at all clear to some of those present. It would be, of course, very desirable, from the standpoint of the industry if the standard grades could be used for welding with some discretion on the part of the designing engineer as to the grade and quality selected for any particular purpose.

I would just like to put a question or two up to this meeting, Mr. Chairman. Has it been found necessary in good practice, to use other than the standard specifications, and also has any particular part of the structural cross-section given difficulty in welding?

President Llewellyn: Have we any information to give Mr. Speller in response to his question? It is a very practical matter. Standard grades are in use today, and I believe they are giving satisfaction. If anybody has found trouble which he attributes to the use of a wrong grade of steel, that information should be given to Mr. Speller either publicly or otherwise.

Mr. Owens: In our work we have used various grades of steel, that is, ship steel, structural steel and flange quality steel and so far have found nothing to indicate that these steels are not satisfactory for the class of work for which used. However, I believe that we ought to keep the carbon content low. For ship steel, I have hopes that the caroon content which is now approximately 0.25 per cent will, as welding is more extensively used in ship construction, be reduced to approximately 0.13 to 0.18. I have found that the higher the carbon content of the steel the greater is the heat effect on the base metal. This can be clearly demonstrated by running a bead on the surface of steels of various carbon content and bending the specimen in the direction of the bead. When bent so that the bead is on the tension side of the specimen the angle of bend will depend on the carbon content. If the specimen is bent with the bead on the compression side of the specimen, the specimens can in general be bent through 360 deg. In making this test the bead of one set of specimens was ground off leaving only the hardened fusion zone, while in another set the bead was allowed to remain as deposited. This effect of carbon content on the strength of the welded joint should be carefully considered when the stress is transmitted excentrically as occurs in lap joints and single strap lap joints. Should the opening between the joint edges in the latter form of joint be less than five times the thickness of the material joined and the carbon content is 0.25 per cent, the specimen will sometimes fail at a stress decidedly below its normal ultimate.

President Llewellyn: That is for ship material.

Mr. Owens: Yes, and we should keep this in mind.

President Llewellyn: We have another paper on a different subject this morning and I think it will be necessary at this time to ask Mr. Vogel if he has anything final to say with regard to the questions and comments that have been made.

Mr. Vogel: Standard grades of structural steel only have been used in our designs and it is my belief that all who have been building buildings by the welding process have used standard grades. I doubt if there is any information available regarding the use of special grades of steel, but if there is it is suggested that the data be transmitted to Mr. Spraragen so that it can be published in the Journal of the American Welding Society.

In conclusion I wish to thank you all very kindly for the very excellent attention given to the paper, and also to thank the gentlemen who so ably discussed the paper.

Discussion paper on "Welding in the Heating and Ventilating Industries,"* by S. E. Dibble, Carnegie Institute of Technology.

Prof. S. E. Dibble, Carnegie Institute of Technology: While President of the American Society of Heating and Ventilating Engineers in Milwaukee I had a very carefully typewritten paper and I varied from it but one paragraph. The next morning in the paper that paragraph appeared and I had about a bushel basket of clippings from all over the world about that one paragraph and nothing about my main paper. So today I am going to carry on reading my paper in regular style.

President Llewellyn: The Society is very much indebted to Professor Dibble for his contribution toward yet another field for the use of welding. There is a little time available for discussion and the meeting is now open for such questions and comments as you may care to make.

Mr. Candy: I may be speaking a little too much this morning, possibly, but I do feel called upon, as doubtless no one else will, to come to the defense of the welding engineer. We have heard mentiond at least twice this morning and possibly three times that all designs should be made by the structural engineer, or the plumbing engineer, or whatever the case may be, and not by the welding engineer. I think I understand the spirit in which those statements are made, but for fear some of you in the room might be led to misconceptions, I do want to make a few statements and they are these:

I will agree that the structural engineer should do the designing and not the welding engineer, providing the structural engineer first becomes a welding engineer, and I do not believe that the structural engineer can become a welding engineer unless he actually learns how to weld, not that he must become an expert welder, but I don't believe that the average structural engineer can appreciate the necessity for having the connections accessible to the welder and can appreciate the

*Paper appears elsewhere in this issue.

points raised by Mr. Danforth relative to the contraction and expansion of the weld metal unless he has actually had some experience with it.

I don't believe that the average structural engineer who doesn't have a welding engineer at his elbow is any safer to turn out a welded structure that is going to stand up and not show failures here or there than the average back-seat driver in an automobile who has never handled a car, could take your new Rolls-Royce down Broadway in after-theatre traffic and come through without at least a bent fender.

So I think that while those statements were made in the right spirit, I do feel that the designers must learn welding problems, and unless they do we will have the necessary evil probably of a welding engineer.

President Llewellyn: Early in the morning the invitation was given for all who have had any trouble in welding, due, as they think, to grade of structural steel, to report the matter to Mr. Speller's committee through Mr. Beck. I don't think that that opportunity is limited to structural steel, but should apply to any field.

Mr. F. N. Speller, National Tube Company: Professor Dibble has made a very good presentation of this important new development in welding of pipe. Pipe welding is so common now in the oil and gas industry that it would be only a small step apparently, to apply it to heating lines. In order to get the greatest progress, the matter must be put up to architects and the users of heating systems in the very best possible light with all the advantages. Professor Dibble, it seems to me, has omitted one or two important points that might be used in this missionary work. In the first place welded pipe is made of a soft, ductile grade of steel particularly adapted to welding. It naturally takes expansion and contraction to the best advantage. But the most important point that Professor Dibble has not mentioned is the favorable effect on the durability of steam lines. Hot water lines present no problem in that respect as there is no deterioration from corrosion, but steam lines, especially return steam lines, are often troublesome. There are always one or two threads exposed, which are cut half way through the pipe wall. The turbulent flow that Professor Dibble referred to tends to cut away the material at the bottom of the pipe. Turbulent flow also greatly accelerates the rate of corrosion and therefore failure usually occurs at the threaded joints. The rate of corrosion is also accelerated by the small air leaks through the system that introduce oxygen into the system. Leaks not only cut down the efficiency of a vacuum system, but greatly accelerate corrosion, due to the oxygen dissolved in the condensate. So everything tends to accelerate the rate of corrosion in horizontal lines of return steam system. The pipe fails at the threads in these lines, I would say, in about half the time that it would if the full section was available, as would be the case in a properly welded line.

In regard to the experimental layout, Professor Dibble suggests, to show the mechanical advantages of welding, that proposition interests me, and I hope he will be able to find means to establish an experimental layout of that kind at the Pittsburgh Station.

Mr. J. W. **Owens**, Newport News Shipbuilding & Drydock Co.: There is one point in the reduction of costs of piping systems which deserves consideration, that is a reduction in the diameter of the bolt circle of flanges. The diameter of the bolt circle of a flange provided with a boss is of necessity larger than that of a flange without a boss. By making the bolt circle smaller the material used in flanges cut from plate material with a torch and welded directly to the pipe can be reduced, the connection is more efficient because the bending moment is decreased, less lagging is required and a neater job is obtained.

The difficulties of introducing such a flange are that it does not match with existing stock flanges and that the bolt circle of cast valves and other fittings cannot be reduced because of the necessary wall thickness. Regardless of these difficulties I feel that the idea should be kept in mind in all installations where a large number of flanges are required and in view of the future development of valves and other fittings of wrought steel.

Mr. F. E. **Rogers**, Air Reduction Sales Co.: For Mr. Owens' information I will say that some of the manufacturers of pipe flanges have developed a flange for butt welding. It makes a very neat, strong and compact fitting, well suited to welding.

Professor Dibble referred to the expansion but did not expand on expansion, that is the advantage of pipe welding in providing for expansion. In combination with bending the welder can provide for many difficult situations that occur in piping work. It is easy to bend with the welding equipment. I have known of jobs where the contractor was confronted with the problem of bending 6-in. pipe, and he accomplished it in the plant itself by using the torch for heating, anchoring the pipe to a column or some other support, and by repeated heatings with two torches brought that pipe around to a nice, smooth curve, using a chain hoist or tackle to apply the necessary force.

With that possibility in view it is easy to see that expansion bends or U-bends, can be produced by the contractor that will compensate for almost any amount of expansion and contraction you are likely to experience in a steam line.

There is one question that I would like to ask Professor Dibble and that is what his experience has been or what the plumbing and heating industry recommends as regards the placing of valves in welded lines; how shall they be put into the line? Shall they be inserted by using threaded nipples? I am speaking of the smaller size 2-in. valves or something like that. Are the nipples to be welded into the line or must we resort to flanges, or how is that particular problem to be handled? Of course, I can see that with certain other apparatus of small size it would be practically necessary to use flanges, because the apparatus probably is designed for flange connection, but I would like to have some information on the valve problem.

Mr. A. **Vogel**, General Electric Company: Mr. Chairman and Gentlemen: In my work as an industrial plant engineer I have occasion to

design large heating and plumbing systems. In the past few years it has been found highly desirable to weld the large heating distribution piping. At one plant there are four buildings each about 600 ft. in length and there has been installed in each building what is known as a double-loop distribution system with expansion bends where required. The smallest pipe in each system is about a 4-in. pipe and the largest is about a 12-in. pipe, but all of the joints throughout are arc welded.

The bends are made in the usual manner except that a straight section about 2 ft. in length is left on the ends of the bend. These piping systems are operated at a maximum pressure of probably not to exceed 5 lb., but they may also be operated at a vacuum of about 10 in., and, necessarily they must be tight. The elimination of gasket leaks alone in the fall of each year has justified the elimination of flanges and the welding of all joints in the entire system.

The problem of making connections for the branch pipes has been quite readily solved by welding in an ordinary coupling to the pipe line at any point desired, or welding in a section of pipe with either a flanged or screw thread end.

Pipe-line systems are now subjected to such wide ranges of pressure as from very high vacuum to pressure up to 1400 lb. per sq. in., that I am going to ask Professor Dibble to describe a type of welded joint used for very high pressure.

There is another element of saving on welded pipe lines and that is in the application of pipe covering. Pipe covering on a welded line is uniform, its entire length and the high cost of making up special pipe covering at the flanges or other fittings is eliminated. The reduction in cost of maintenance, plus the simplification of the pipe covering and the reduction in cost of erecting large welded lines, justifies completely welding-heating distribution systems.

The question has been frequently asked regarding what to do in case it becomes necessary to remove a section of pipe. Those who are acquainted with the heating industry know that it has previously been standard practice to insert flanges at regular intervals so that piping could be readily disassembled. That practice has been discontinued. If it becomes necessary to take out a section of piping, it is removed by using the torch and then a new section is welded in place.

In erection alone a very considerable saving is made in welded pipe lines. Pipe lines are now assembled and welded on the floor in sections up to 60 ft. in length and then the section hoisted into position.

In the plumbing industry it has been found desirable to weld up many branch connections in order to fabricate a manifold. This development has been carried out probably to the best advantage by a Philadelphia firm by the name of Boon & Sample, Inc., with very satisfactory results.

President Llewellyn: Professor Dibble, will you make one bite of your replies to the questions?

Professor Dibble: Mr. Vogel's questions as to the type of joint to use on high-pressure work I will show on the board. The ordinary butt weld can be used, slipping over the pipe a larger section, and then welding a fillet weld around between the larger pipe and the pipe itself, making a positive weld for strength and for tightness between the main pipe and the sleeve, as well as making the butt weld for strength and tightness. It has been used to advantage in a number of instances.

Now, then, I would like to mention the covering of pipe. I think Mr. Owens brought that question up. It is a great saving in the covering of pipe where piping is welded. There are no fittings; there are no flanges and the pipe covering can be put on almost in straightaway fashion cutting down the amount of labor and cost of molding the fittings.

I would like to apologize to Mr. Candy and all the welding engineers in the room. No offense was meant. The item I wanted to get across was the fact that the skilled mechanics must know how to weld and present plumbing and heating engineers must know how to use it and where. They can only get that information from the welding engineer.

The matter of placing valves in main lines, at the present time I only have to suggest that threads must be used. Our small size valves are all threaded and it would not be possible to change that industry right away. So that a short nipple or a coupling can be welded into the main and a valve placed into the coupling or the nipple. That does not present any very serious problem.

Mr. Speller's suggestion as to the value in the lessening of corrosion is certainly so and I want to second all that he says. The tightness of a welded job is also important because we are getting today not only high pressures but we are getting 18 and 20 in. of vacuum on some of our different systems and tightness plays an extremely important part, and a weld is the answer in many, many cases. I think that is all I have to say. Thank you.

President Llewellyn: We have run a little beyond our scheduled time. The next session will occur at two o'clock in this room this afternoon.

Thursday Afternoon, April 25, 1929.—The Fourth Technical Session convened at 2:15 p. m., Mr. A. G. Oehler presiding.

Chairman A. G. Oehler, Railway Electrical Engineer: Mr. President and Gentlemen: I don't think it has ever been my privilege to take active part in a meeting of more peculiar interest to me. In my humble opinion these two papers to be presented to you this afternoon have great potential importance. Perhaps the reason they are of particular interest to me is that they are both in the transportation field. Then, also, they are made interesting by contrast. One has to do with aircraft and very thin sections and the other is an application of thermit which is most suitable to heavy sections. And that isn't all; in one case the welding

is applied to uncommonly used metals and in the other case its application is an innovation which none of the old-timers in the railroad field are very ready to accept.

Certainly, having heard these papers, no one can leave this meeting with the idea that they know all about welding or what is going to be done with it.

The first paper is entitled, "Welding in the Aircraft Industry," by Mr. R. M. Mock, of the Bellanca Aircraft Corporation.

Discussion paper on "Welding in the Aircraft Industry,"* by R. M. Mock, Bellanca Aircraft Corporation.

In view of the extreme difference between the two papers, I think it will probably be desirable to dispense with the bulk of the discussion on the aircraft paper before we start the other one. I might offer one suggestion. Mr. Mock has mentioned the desirability of using chrome molybdenum steel in aircraft construction. I believe there is considerable research work being done on that in some quarters now. If there is someone here who could shed light on the effect of welding on this material, I think it would be particularly appropriate. Isn't there some gas welder in the room that can help us out on this?

Mr. Mock: To my knowledge all the research that is being carried on in aircraft welding is being confined to chrome molybdenum tubing and for that reason we have nothing to contrast it with. From our results we know what we may expect of chrome molybdenum but we don't know what may be obtained in the other materials. I know of no extensive tests that are being conducted in carbon steel.

Chairman Oehler: Would you care to enlarge at all on that angle of it—just what does welding do to chrome molybdenum?

Mr. Mock: It appears that chrome molybdenum has a certain air-hardened property which in our light-gage material gives a form of heat treatment on cooling. That is the impression that we have and for that reason we buy our sheet stock in the annealed state and after working it, bending it and forming it in the annealed state, when we weld it, the heat of welding and the air cooling gives it an air-hardening which is equivalent to an ordinary normalizing. After welding we calculate our chrome molybdenum to have a strength of normalized material of 95,000 lb. per sq. in. Heavy parts are normalized after welding.

We obtain all our tubing in the heat-treated state. There is an annealed portion adjacent to the weld which is the reason why we can only use a coefficient of fixity of half of that which is normally required. We calculate our long columns half way between a pin joint and a full joint. We go to all sorts of extremes to eliminate continued annealed areas around a tube. If we have a tube which is subject to bending stresses, we don't want to have an annealed portion completely circling that tube where the bending occurs, because if

*Paper published in April, 1929, issue of Journal of A.W.S.

we do we are positive it is going to fail in that annealed portion. We often go to very odd-looking shapes in order to distribute that annealed portion along the tube rather than have it completely circling around it. We sometimes have it zig-zag up and down the tube and going around in this way, producing a sort of fish mouth.

Chairman Oehler: Any one care to enlarge further on this angle?

President Llewellyn: I confess to ignorance regarding one expression that Mr. Mock used. I don't know and would like to know exactly what is meant by the coefficient of fixity.

Mr. Mock: In all columns in all sorts of structural work the column strength depends upon the method with which the ends are fixed. If we have a long column or a beam, you might say, subjected to an axial load, the ends are pin jointed or free to move, we can get a higher fiber stress in that column and it is much weaker than if the ends were rigidly supported, such as if they were set in concrete. If we took a long tube and set it in concrete we might say it had complete fixity at the end; while if it was supported on a point at the end we would say it was pin-jointed. We calculate something half way between because of the fact that our annealed portion is not full fixity.

President Llewellyn: Very largely, but not quite. In the structural field, we have the same proposition, but we express it a little bit differently. Of course I understand that the strength of a strut depends on its degree of fixity, but I don't quite know what Mr. Mock means when he speaks of "coefficient." I don't know what he is comparing with as a starting point.

Mr. Mock: In our column formula, rather than use the ordinary formula coefficient of fixity of one and a pin-joint coefficient of fixity of a quarter, which is usual in column calculations, we multiply everything by four. We therefore calculate a completely fixed joint instead of one as four, and a pin joint instead of calling it a quarter, we call it one.

Mr. Goldmark: I would like to ask Mr. Mock which of the two is stronger. I understood him to say the pin-jointed one was stronger.

Mr. Mock: A fixed joint at the end for the same section of tube will give a much stronger column. If we have a tube of a certain diameter and wall thickness and a certain length, all those factors being fixed, if we fix it at the end, it will stand much more compression than if it was pin-jointed at the end.

Chairman Oehler: Mr. Mock has in a sense thrown down the gauntlet to the American Welding Society by his declaration that the average welder's knowledge is a handicap and that they find it more satisfactory and cheaper to educate green men in the art of welding aircraft structures than to use experienced men. I think perhaps there is work in order on the part of the Society to correct the situation in which it must learn how to weld aircraft from the aircraft builders.

I think we can temporarily discontinue the discussion at this time. However, you can consider the meeting open, after the reading of the next paper, to further discussion of Mr. Mock's paper.

For the next little while I would like to have you get in mind a section of railroad track in main-line, Class I, open-track road, all made in one piece, a thousand feet long. This noon I asked a Thermit representative: "How do you account for contraction and expansion caused by daily and seasonal changes of temperature, and it was explained to me that the joints are made of spring steel.

The next speaker, I think, can enlarge on my rather meagre knowledge of this application. The title of the paper is, "Thermit Welding of Rail Joints for Main Line Track of Steam Railroads." It will be presented by Mr. J. H. Deppeler of the Metal and Thermit Corporation, a Past President of the Society.

Discussion Paper on "Thermit Welding of Rail Joints for Main Line Track of Steam Railroads,"* by J. H. Deppeler, Metal & Thermit Corp.

Chairman Oehler: Some years ago I stood with a track man on a double track line on the Northern Pacific between Tacoma and Seattle and I said to the man, "What are those things for?" pointing to an anti-creeping device on the rail and he said, "We put those things on there so that we don't have to go down to Tacoma every so often and take off a rail length and carry it up to Seattle."

Will we be satisfied when we weld track as one continuous piece from New York to Seattle, to be obliged to cut off a section at Seattle every so often and bring it down to New York. I would like to hear some comments on it.

President Llewellyn: We have had in previous sessions some remarkable examples of the manner in which welding has thrown light on other methods of fabrication. In this wonderful paper, we have an example of how welding may perhaps solve the problems of the steel mill. These are the days of continuous furnaces. We already have continuous soaking pits and continuous bar mills. We have mills with cylindrical rolls that run continuously. I see that in future our rail mills can omit their batteries of saws entirely. All that we shall have to do will be to connect the end of the mill with the railroad on which the rails are to be laid, say, in Chicago, and keep on rolling one continuous rail which will be supported on cars and snake out to San Francisco. The only trouble is, what will we do at the swing bridges? [Laughter.]

Mr. J. C. Lincoln, Lincoln Electric Co.: There is one question I would like to ask Mr. Deppeler. If I understand him correctly, his regular thermit joint introduces at the rail ends a high carbon piece of filler and the thermit metal goes around the rail ends below the filler and the compression on this filler piece at the rail head, due to the contraction of the thermit metal as it cools, forms a so-called pressure weld so that the wear of this filler piece and the wear of the rail are approximately the same. I understood him to say that in the joint which he proposes to use for steam road work, the filler will be somewhat smaller and made of soft steel. I am inquiring if that is correct.

Mr. Deppeler: In our development of the pressure weld, we allow

*Paper published in June, 1929, issue of Journal of A.W.S.

the rail heads to come tight together. The contact surfaces run down about an inch below the rail and then we undercut either one or both rails for the fusion weld below. We pressure weld the rail heads themselves together without any intermediate piece and that pressure weld extends to an inch below the head when the weld is made, the regular thermit weld is all the way around.

Mr. Owens: You must have noticed that Mr. Deppeler used the term "pressure thermit welding." This is a new term with the Thermit Company and Mr. Deppeler's use of it is the result of his cooperation with the Nomenclature Committee. In this connection Mr. Deppeler has informed me that he proposes to revise all of his company's literature so as to incorporate in it all of the terms which have been tentatively approved by the Nomenclature Committee. I will take this opportunity to publicly congratulate Mr. Deppeler on his cooperation with this Committee and which will involve a considerable expense to bring his literature in line with the society's Nomenclature. It is hoped, therefore, that other manufacturers will cooperate along the same line so that within a year or two we will talk in the same terms and have recognized welding nomenclature. The report of the Nomenclature Definitions and Symbols committee will shortly be published and may I ask everyone present to assist in its extensive use.

Chairman Oehler: Mr. Deppeler, you didn't show any pictures of your own apparatus. I wonder if you would tell me or tell us why you expressed a preference for a file where no power was available to the use of tools operated by a portable gas engine driven electric generator or air compressor.

Mr. Deppeler: The clamp that we have developed looks almost the same as the second one that I showed you of the German clamps. It has diagonal bolts tending to line the rail against a straight end on the opposite side of the clamp. The clamp weighs, I think, 325 pounds. We have a device operated with one lever which lifts the clamp off and rolls it on to the next joint. We like to use a lighter clamp. Possibly we will get alloy steels or something which will enable us to use a lighter clamp, but we would rather have something which is surely going to be effective.

On the second question, the danger in any type of rotary wheel grinder or machine is the gouging in of the running surface of the rail due to carelessness in the grinding operation. We, therefore, like for this railroad thing to have something which will give a rubbing action. Of course, there are power-driven machines that rub the surface of the rail. If we can, we will develop one which will be operated by a small gasoline motor, but the excess metal seems to come off so easily by this little hand-operated device that it may be that it will be easier for us to continue the practice of hand machining due to its portability than to try to have something heavier to carry along the right of way.

In their development at least, the Germans have found it important to do this work on the side of the right of way where the ballast usually runs down to a ditch and the conditions are anything but

perfect. The traffic can't be interrupted in any way. Between trains they take this welded stretch and snake it over into place and spike it down. Portability, therefore, is of considerable importance and also it is important to keep off the right of way all you can.

Chairman Oehler: The membership present this afternoon seems in a mood to receive rather than to disseminate information and in compliance with your apparent desire, I am going to call for some more information. This has to do with a proposed method of fixing working stresses in pressure vessels and Mr. J. C. Lincoln has something to offer on that subject.

Ductility and Tensile Strength of Welds for Pressure Vessels*

BY J. C. LINCOLN†

OUR company has a method of welding by the use of the carbon arc. This method was not in the minds of the Boiler Code Committee when the code governing the manufacture of unfired pressure vessels was written.

In order to specifically get the Boiler Code Committee to recognize our process, I approached them asking for specific recognition of the carbon arc welding process.

In this connection it became necessary to specify the quality of the welding done by the carbon arc process and after taking the matter up with Mr. Obert, who formerly acted for a good many years as secretary of the Boiler Code Committee, it seems advisable to suggest changes in paragraphs U-68 and U-71, and it further seems advisable to suggest to the Boiler Code Committee that instead of making the ruling for the carbon arc process only on matters covered by these two paragraphs that the Boiler Code Committee consider the broad subject of welded joints made by any fusion process.

Paragraph U-68 at the present time reads as follows:

"When properly welded by the fusion process the strength of the joint may be calculated on a maximum unit working stress (S) of 5600 lb. per sq. in."

It was suggested to the Boiler Code Committee that this paragraph be changed to read:

"When properly welded by the fusion process, the strength may be calculated on a maxiumum unit working stress (S) as given in paragraph U-71."

The present paragraph U-71 reads as follows:

"Method of Welding. Longitudinal seams shall be of double-V type, that is, welded from each side halfway through the sheet. Girth and head seams may be of the single-V type, that is, welded entirely through

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from the outside. Double-V welds shall be reinforced at the center of the weld on each side of the plate by at least 25 per cent of the plate thickness. Single-V welds shall extend entirely through the plate and shall be reinforced at the center of the weld by not over 20 per cent of plate thickness. All welds shall be of sound metal, thoroughly fused to

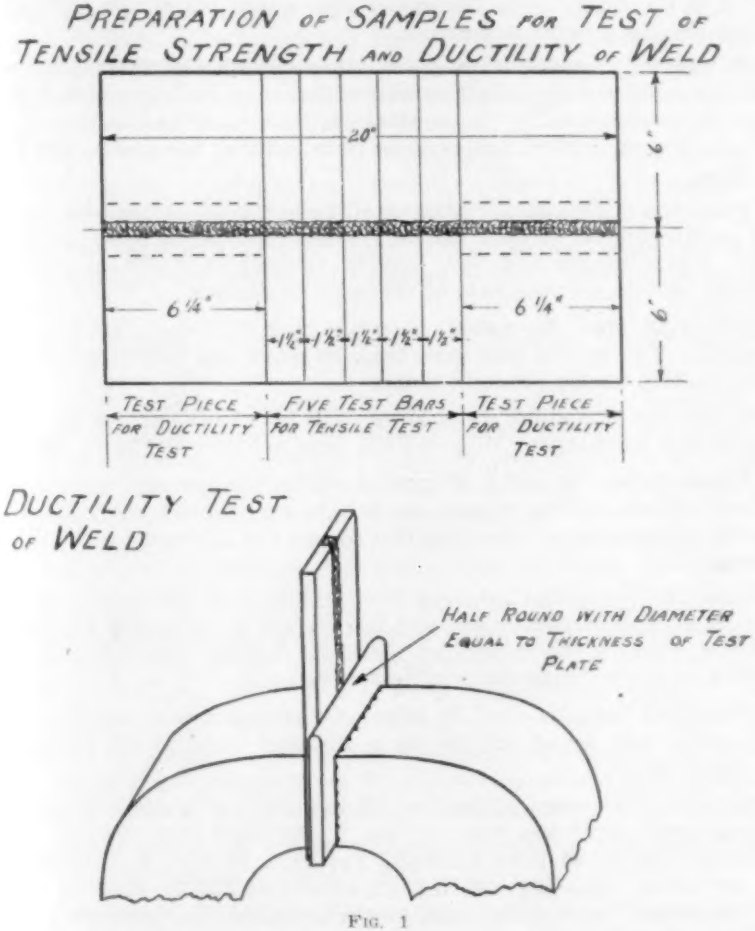
PREPARATION OF SAMPLES FOR TEST OF TENSILE STRENGTH AND DUCTILITY OF WELD
20"
6"
6"
6 1/4"
6 1/4"
1 1/4" 1 1/2" 1 1/2" 1 1/2" 1 1/2"
TEST PIECE FOR DUCTILITY TEST
FIVE TEST BARS FOR TENSILE TEST
TEST PIECE FOR DUCTILITY TEST
DUCTILITY TEST OF WELD
HALF ROUND WITH DIAMETER EQUAL TO THICKNESS OF TEST PLATE

FIG. 1

the sides of the V for its entire depth. Sheets must not be allowed to lap during welding. In material ¼-in or less in thickness, the longitudinal seams need not be beveled. In material less than ¼-in thick, beveling the heads will be sufficient, and the shell need not be beveled at the head seams. One side of each girth shall be beveled.

"There shall be no valley either at the edge or in the center of the joint, and the weld shall be so built up that the welded metal will present a gradual increase in thickness from the surface of the sheet to the center of the weld.

"At no point shall the sheet on one side of the joint be offset with the sheet on the other side of the joint in excess of one-quarter of the minimum thickness of the sheets, or plates."

It will be noted that Paragraph U-71 as at present gives in considerable detail the method by which the joint should be made. It was suggested to the Boiler Code Committee that a new paragraph U-71 be submitted for the present paragraph.

The new Paragraph U-71 reads as follows: "METHOD OF WELDING. The method of welding shall be that which shall develop the best results from the process used. The method shall be tested by welding together two plates 6 in. x 20 in. into a plate 12 in. x 20 in. for tensile and ductility tests.

"From the middle of the plate shall be cut five test bars 1½ in. wide. The outside 6¼ in. on each side of the test plate being used for ductility tests. These tensile test bars may be reduced in width to 1 in. for a distance of 4 in. on each side of the weld, if desired.

"The weld shall be tested as made both for ductility and tensile strength. The tensile test bars shall be given the standard test to destruction and tensile strength noted.

"No welder or method of welding shall be allowed in which any test bars welded by that welder or method breaks below 40,000 lb. per sq. in.

"A permissible maximum tensile strength of 18 per cent of the average of five test bars welded by any method shall be allowed. Additional permissible maximum tensile strength (S) shall be allowed for ductility, as follows:

"From the two plates reserved for ductility tests the extra metal may be removed if desired to make two test bars 2 in. wide and 6¼ in. long, with the weld in the middle of the 2 in. width. The removal of the metal is simply to make the bend test more easily.

"These two samples shall be bent at right angles to the line of the weld over a half round bar having a diameter equal to the thickness of the sheets joined.

"No additional strength shall be allowed for any method in which the samples tested bend less than 20 deg. in the bend test. For 20 deg. an additional 250 lb. shall be allowed. For each 10 deg. in addition to 20 deg. up to and including 180 deg. an additional 250 lb. shall be allowed. The allowance for ductility shall be determined by the sample having the lower ductility.

"An inspector can insist that any welder or any method at any time shall be tested in the manner indicated above and a permissible maximum tensile strength (S) allowed to that method or to that welder determined as set forth.

"The inspector shall not allow the use of any welder or any method that fails to pass the minimum test."

I would like to see the Welding Industry get behind this suggestion or one somewhat similar to it as it is reasonable to believe that if the

Welding Industry suggests some such paragraph as this that the Boiler Code Committee would very seriously consider the suggestion.

As I see it, the advantages of this new paragraph U-71 are as follows:

First, and most important. It gives the inspector the power to test any welder at any time for his skill and to rule off the job a poor welder. All of us who are acquainted with welding, know that practically all welding is entirely satisfactory but that the small percentage of poor welds which are made have done more to retard the art of welding than any other one thing. Those who are interested in the welding art are above everything else interested in seeing to it that some means is provided so that only good welding shall be done on important work.

As far as I know, no rules by any regulatory body have been suggested up to the present time which would make this possible.

This new paragraph U-71 does make it possible for inspectors to be certain that the welder knows his business and is capable of making a good weld.

I do not think that the importance of this provision can be exaggerated.

Second—The new paragraph U-71 gives a permissible strength of 9000 lb. per sq. in. on steel which has a breaking strength of 50,000 lb. when it is so welded that the samples break outside of the weld. I think that those who are engaged in the welding industry as well as members of the Boiler Code Committee will agree that when a weld is made so that the weld is stronger than the parent metal that an allowable strength of 18 per cent of the strength of the parent metal is conservative.

I believe that the only reason that the low value of 5600 lb. as fixed by the Boiler Code Committee in the present code was that there were no means by which the Boiler Code Committee could be certain of the quality of the weld. A good weld is easily capable of carrying 9000 lb. and a poor weld ought not to be allowed at all.

The rules that determine the allowable strength of a weld in an unfired pressure vessel should be governed by the quality of the good weld and should not be effected by the possibility of making poor welds.

As suggested above, no welder who cannot make a good weld should not be allowed to work on important work.

Third—Ductility of welded joints is improving very rapidly at the present time and we all admit that a weld having good tensile strength and a high ductility is a better weld than one having low ductility.

Additional tensile strength is allowed as a premium for high ductility in the suggested paragraph and the maximum additional strength allowed for a weld which will stand the same bending test that the original plate stands is 4000 lb. per inch.

I do not believe that any one would consider it unreasonable to allow a strain of 13,000 lb. per sq. in. for a butt weld on a welded plate up to $\frac{5}{8}$ in. thick when the weld is ductile enough to bend 180 deg. over a rod

having the same diameter as the thickness of the plate and when the weld is so made that the tensile test samples break outside of the weld.

I am not arguing for accepting the allowances which have been suggested but I am urging that a premium for ductility be allowed and that a ductile weld be allowed to carry a greater strain than one which is not ductile.

If the particular figures suggested in this paragraph are not satisfactory to the welding industry as a whole, they can be altered; but I urge that the welding industry back up some such scheme of determining an allowable strength of welds.

It is reasonable to suppose that the Boiler Code Committee would give a great deal of weight to a proposal somewhat similar to the above, coming from the welding industry as a whole, as a request to the Boiler Code Committee for new allowable tensile strength in butt welded joints provided that means can be assured that poor welders and therefore poor welding can be eliminated from consideration.

Mr. Lincoln: I would like to suggest, in order to get this thing before the Welding Industry, that an action somewhat similar to what I have suggested be taken by the Welding Society.

Mr. E. H. Ewertz, Consulting Engineer: Mr. Chairman and Gentlemen: As Chairman of the Pressure Vessel Committee, having a membership from both the American Welding Society and the American Society of Mechanical Engineers, I have knowledge of what is transpiring in connection with the committee's work with non-fired pressure vessels. We have had a number of meetings and I may say that on the committee are a number of members of the Boiler Code Committee.

The attitude of the Boiler Code Committee, as I gather, is that they feel it is necessary for them to prescribe rules that are first of all safe and, second, are readily applicable to tanks built anywhere.

The Pressure Vessel Committee is contemplating a test of a great many tanks welded by various processes, primarily all tanks being of a given design and welded under prescribed procedure control. It hopes that the results from such a test will shown conclusively that a very much higher figure could be established in the code than that in it now, and that it will be at least 8000 lb.

Considering what Mr. Lincoln has presented here this afternoon, I can't help but think back to a statement made at one of our meetings by an engineer representing a very large user of tanks and also designer of tanks. If an engineer, a designing engineer, is requested to make up a design for a tank for a specific purpose, he will have to assume a definite allowance in his calculations for the strength of the weld. If there is to be variation due to different processes, he would also have to prescribe on his plan that these tanks must be welded by a specific process and by men who have qualified.

Assume that an engineer designs a tank with 13,000 lb. stress in the

welded joint and that tank was manufactured by a concern which was not conscientious enough to use the prescribed method of welding but adopted some other which appeared to them just as satisfactory, we would have a rather odd condition entirely beyond the control of the Boiler Code Committee and yet if destructive tests were made it would apparently show that the Boiler Code Committee had allowed too high stresses as it might not be found that the shop had not followed the proper method prescribed by the designing engineer.

If the Boiler Code Committee specify stresses on a sliding scale, based on processes and on tests of ductility found from actual samples, then the engineer would be in a rather awkward position because he could not possibly predetermine what might happen in the test, making it necessary to establish a very definite allowance for five or six or more different kinds of welding methods. While I can't speak for the Boiler Code Committee, I am perfectly frank to say that I don't think they are in the frame of mind today to undertake such a difficult and possibly dangerous procedure. I think rather we are going to get a ruling which will be universal for methods of welding and with the necessity of qualifying the welders and following a definite procedure.

Somebody said a short time ago that the margin of safety that engineers use in their calculations is a margin to make up for errors and mistakes, and there is no doubt in the world but we have escaped disaster in the past in many instances due to the fact that a large margin of safety was used in the calculations of construction.

If in an average weld, good weld, say 45,000 lb. the margin of safety of five was applied as it is in most other engineering, we would have an allowable stress per square inch of weld of 9000 lb. Assume that a welder would be feeling out of sorts some day when he got to work and not make as good a weld as he ordinarily could, it is difficult to assume from a practical standpoint that the total result of his activity wouldn't be equal to at least half of what he would normally do still leaving a margin of safety of two and a half. It is quite true that we want good welders and we will have good welders when we acquire good supervision and proper training and tests of our welders, but it is equally necessary in my opinion and probably more necessary that we have proper engineering in connection with design of the parts that are to be welded, the proper selection of material and the proper set-up for the man to work under.

Not a long time ago I was asked to inspect some welding made some distance away from here. They had very good welders on the job. They had perfect machinery. They used the right kind of material and still the welds as a general thing were terrible. The main reason for the poor result was due to the welders being compelled by orders from the superior officer to weld units together that had been given from one to three coats of paint prior to welding. Obviously, the results were disastrous.

In other work that we have followed up from time to time, we find

that welders are asked to perform work on designs that are almost childish and yet the welder is blamed if the result is not satisfactory, when the fault lays with the supervising or engineering force.

I agree with Mr. Lincoln that with proper designing and testing, and with trained welders, the allowance for stresses might safely be put up to one-fifth of what we consider a good weld, but I don't agree on establishing a great many different allowances as the manufacturing is out of the hands of the designing engineer and inspection and testing is only to verify the good quality of work done.

Mr. Crowe: I think the American Welding Society already has a committee which is cooperating with the American Society of Mechanical Engineers looking toward a change in paragraph U71, but it seems to me, would hesitate before putting up to the Mechanical Engineers a bend test, such as Mr. Lincoln has outlined, where the bend is at right angles to the weld instead of parallel to the weld.

President Llewellyn: I may explain one feature. The suggestion that Mr. Lincoln has made has been presented officially to the Society and will come before the Executive Committee at its next meeting, will full knowledge of other committees that Mr. Crowe refers to, but it seemed to be desirable to secure the informal views of those members who are here present on this question and for that reason the subject was introduced at this time.

As I understand it, Mr. Lincoln expects at this meeting merely an expression of informal views.

Mr. Hobart: It seems to me that the sliding scale limit of what you would be allowed to do which is a feature of the suggestion made by Mr. Lincoln would present considerable difficulties, as Mr. Ewertz said, but I don't agree with Mr. Crowe that Mr. Lincoln's bending test is not a good bending test. It seems to me that it has considerable advantages over the usual kind of bending test. I believe in Mr. Lincoln's bending test but I do not care much for the part of his proposition involving a sliding scale of limits.

Mr. C. H. Jennings, Westinghouse Electric & Mfg. Co.: In discussing this type of bend test, I would like to make the following comments:

First: I do not feel that this type of bend test will give the information that is desired of a joint.

It is a well known fact that the physical properties of weld metal very greatly when stressed parallel or perpendicular to the direction of deposition. Therefore, if we take a butt weld for an example and keep the above statement in mind, it is obvious that if the weld metal is stressed perpendicular to the direction of the joint and parallel to the direction of the joint that two entirely different results will be obtained.

Also, in nearly every butt weld joint that is made, the load is applied in such a manner as to stress the deposited metal perpendicular to the direction of the joint.

For this reason I feel that the bend test as proposed, which stresses the metal in the direction parallel to the joint, will not furnish the proper information that is required of the joint, and is not the solution of the problem.

Second: In any bend test of a welded joint, one important factor must be taken into consideration. This factor is the height of the reinforcement of the weld.

If a welded specimen is tested in bending, the stress and elongation of any fiber is not only a function of the radius of curvature that the piece assumes and the angle through which it bends, but it is also a function of its distance to the center of curvature. Therefore, assuming the same radius of curvature, a test piece on which the reinforcing weld metal is built high above the surfaces of the plates will fail at a much smaller bending angle than a similar piece with no reinforcement. This would tend to indicate that the former weld had a lower ductility than the latter, but actually this might not be the case.

Consequently, if a bend test is to be used, good results can only be obtained if the weld metal is machined flush with the surface of the plates.

Mr. Lincoln: The suggestion is simply the weld shall be tested as made. You see there are two conflicting requirements. In order to get a maximum tensile strength here we want to have a weld built up. In order to get a maximum amount of bending we would like to have the thickness of the weld cut down. The only thing I am interested in is this: I do think we all admit that a ductile weld is better than one that is not ductile. I think you all admit that. If a ductile weld is better than one which is not ductile, tensile strength being the same, we ought to give some advantage to the ductile weld as compared to the one which is not ductile. This is a method of giving the ductile weld an advantage over the non-ductile weld.

Mr. **Owens:** As you all know the question of evaluating a weld on the basis of ductility and tensile strength was strongly sponsored by the late Mr. S. W. Miller. I am in favor of any welding process that will give us a weld having the physical, chemical and metallurgical characteristics approaching that of the base metal and anything that we can do to secure this ultimate goal should be encouraged. Mr. Ewertz has clearly stated the situation as it stands at present, however I cannot, as yet, see how we can differentiate between small gradations of ductility. The methods so far suggested seem to me to take the design out of the hands of the designer and put it in the hands of the inspector in the shop. If ductility is taken into account it must be known when the design is made because the thickness of material ordered will be dependent on the unit stress to be used in the design of the welded joint. All the inspector can do is to insure that the welds are sound and that the design requirements are secured.

The test suggested by Mr. Lincoln is all right except that all reinforcement should be removed before the specimen is bent. When

determining ductility I bend the specimen both transversely and longitudinally with respect to the weld. I do not see how we are going to obtain a true value of a weld in tension and bending tests by leaving the reinforcement on the specimen, as amount of reinforcement is a very variable factor. The Structural Steel Committee has given due regard to this in design requirements for the strength of both fillet and butt welds is based on the throat section exclusive of reinforcement. Furthermore, in order to secure comparable results with different processes, with different thicknesses of material and with welds made by various investigators and users, it will be necessary to have a common basis, which can only be secured by the removal of the reinforcement. To me this is fundamental.

President Llewellyn: If I may rise a second time, one is not in position now to favor or oppose this suggestion, but I do think that a little light will be thrown on the question of the sliding scale which has been mentioned by two of the discussers who regard it as not feasible. I believe there is already in force, and has been for twenty or thirty years, a sliding scale basis whereby the permissible unit stress allowed on a certain class of boilers is one-sixth of what later may be found to be the ultimate tensile strength of the weakest plate entering into that boiler. I am referring to the rules of the U. S. Steamboat Inspection Service.

It may be objected that it is impossible to know ahead of time when you design a boiler what strength of plates will be used. Not necessarily. The designer assumes results that he knows can be secured and the manufacturer lives up to those figures by producing plates that are somewhat higher than the assumption. Those rules are still in effect, I believe. They were up to a few years ago.

Mr. C. W. Obert, Union Carbide and Carbon Res. Labs.: I am not familiar with the so-called marine steel, but I have a very general idea that marine steel is more costly than the class of steel plate used in stationary boilers. I understand that it costs about $20.00 a ton more than plate for stationary boilers, which is due to the fact that the inspector stationed in the steel mill can call for a test specimen out of any part of the plate he selects and the test pulled on that specimen is what governs the working stress to be used. I think that is correct, but I would want to have that information vouched for by the marine inspectors.

I would like to comment on what has been said here by several in regard to the impracticability of working on a sliding scale of allowable working stresses for welded joints. That question came up when Mr. S. W. Miller originally made his suggestion for this so-called bend-test formula. This formula has not been brought out in the proceedings of the Welding Society, so perhaps the membership at large may not be familiar with it. I will therefore explain that the suggestion first came to the A. S. M. E. Boiler Code Committee and the Boiler Code Committee referred the recommendation as a promising basis for measuring ductility, to the American Welding Society for its consideration, with the idea that if the suggestion proved satisfactory

to the Welding Society the Boiler Code Committee would very likely make use of it in some way in revising the Unfired Pressure Vessel Code for greater allowable stresses on welded joints.

When the proposed formula and method came before the two committees of the Welding Society that had been instructed to consider the question of its practicability, it was objected to by several members mainly on the basis of the fact that they understood that when a vessel was to be made, a test specimen would have to be worked out or made up at the same time the vessel was welded and then be tested, and that the inspector on the job would then rule on the basis of the test result what that particular tank would be allowed as far as working pressure is concerned.

If that assumption carried and it were to work out that way, it would of course be an impractical and unworkable plan. There might be two tanks just alike in all dimensions; one would be allowed a 9000 lb. working stress and another one perhaps 8500, which wouldn't be logical. The tank manufacturers objected very strongly, particularly those that put these tanks out in thousand lots, because they couldn't stand for the uncertainty of having variable pressures on those thousands of tanks all built alike. Some scheme had to be worked out that would allow the designer and the manufacturer to select a certain class of steel and welding rod for a certain series of dimensions and get a perfectly definite working pressure allowed on it. When the so-called bend test formula was presented to the National Board of Boiler and Pressure Vessel Inspectors at its annual meeting last June the general plan seemed to be logical to those men who have the duty of applying these code rules in the various States; it seemed to not only apply to any test method on any particular tank as it came through, but also to set up an approval method for the welding process of any particular manufacturer.

If, for instance, any large company were to go before this National Board of Boiler Inspectors and apply for a rating on a particular test of welded joint, using a certain set-up of base metal and welding rods and process of welding, the inspectors thought that this method would give a quick answer to that question. They feel that if this bend-test method should be approved it would be possible for them to carry out sample tests of specimens made up to represent the process and the result to be put in any particular tank and, by use of the bend-test formula, work out an allowable working stress for that particular set-up of conditions.

They have a very definite precedent to follow in that the Canadian provinces, who handle their inspection work a little differently from what we do over here, require designs of boilers and tanks to be submitted to them and they rate and approve them in advance. For instance, if a boiler or a tank is approved in Ontario once, that particular boiler or tank design including that particular set-up of materials and conditions, can then be built for that pressure for all time; it never has to be re-approved and that approval stands for that particular design on file in the Boiler Inspector's office in Ontario for as

many units as the concern wants to make. The boiler inspectors seemed to favor applying that same procedure, if this bend test formula were to be approved.

To refer to Mr. J. C. Lincoln's recommendation, I feel that Mr. Lincoln gained a lot of valuable information by sitting in at some of the Boiler Code Committee meetings during the past fall and winter. He has seemed to get more directly and more successfully the Boiler Code Committee's point of view on this welding problem. It seems as though at almost every meeting of the Boiler Code Committee during the last year or two, we have had snarls in regard to questions on welding. I view his recommendation as an attempt to offer a somewhat different thought on the much talked of ductility factor. The previous recommendation that came from Mr. S. W. Miller has been forcefully objected to from various sources and I think it is very fortunate that Mr. Lincoln has offered an alternate. He has heard and known of the other recommendation and he comes along with one that eliminates and avoids the use of a formula. It puts the matter on a sliding scale basis and steps up according to results, and the method of figuring it certainly would be much more simple for anybody in the field to work out and check up on results.

I am personally very anxious to see his plan discussed when the proper time comes. His suggestion is excellent. Personally, I think the stresses he sets forth in his recommendation are a little high. There is a possibility of getting with a perfect bend test, a weld rating as high as 13,000 lb. per square inch allowable stress, which appears to me just a little bit high. However, if the method appealed to the members of the Welding Society, certainly that feature could be adjusted properly.

The main thing is not so much to determine just what the stresses should be, but to work out some plan by which we can find a logical and reasonable method of rating welds. That is the big problem now before the Boiler Code Committee. It is the question that has been holding back action in the Boiler Code Committee toward making greater allowances for welding. Mr. Ewertz has outlined the situation very clearly and very definitely. I don't want to be understood as taking issue with him on the matter. He has put the problem to you just as it is in relation to what has been going on in the Joint Pressure Vessel Committee. I am merely attempting to fill in the gaps that seem to have been overlooked by some of the discussors and point out that the Boiler Code Committee is anxious to have something of this kind that is dependable and that can be relied upon to give safe and workable results.

About a year ago a cooperative relationship was established between the Boiler Code Committee and the Welding Society. That is a very fortunate thing because it puts in your hands the opportunity of thrashing out these things and recommending to the Boiler Code Committee in an authoritative way. The Boiler Code Committee will listen to and consider what you think is right in this matter of establishing proper allowances for welding. This Society is representative of the

welding field and it is the logical one to set these standards and limits.

If, therefore, you can work out something along the line that Mr. Lincoln has suggested, it would be a great help and I know the Boiler Code Committee will consider it very seriously when it comes to them. The Boiler Code Committee is favorable to the idea of a ductility factor in some form. From the very beginning of its work, it has looked to ductility as one of the important features of any pressure vessel structure and when this thought first came forward as an agency in connection with the problem of rating welds, it immediately made a favorable impression. Of course, it is a struggle to properly work out that idea but I think that this organization ought to consider every possible means of finding some reasonable way of rating boilers, either along the lines suggested, or, if they are found unsatisfactory, to develop something that it can recommend.

Mr. Owens: Mr. Obert has expressed my viewpoint very clearly and I am in full sympathy with all he had said. What I meant was that it was necessary for the designers to have the sliding scale in order to design and order his material. If Mr. Lincoln's suggestion aids us to overcome the practical difficulties encountered with the scheme proposed by Mr. Miller, we will be on the right track.

Mr. Lincoln: I had hoped somebody was going to say some kind words about what I thought was the most valuable suggestion I made. I thought the best thing I suggested there was to give the inspector some means of being sure he was going to get a good weld. I think that is the most valuable thing in that suggestion. It gives the Boiler Code Committee a means of being sure that the welds they are going to pass on are good welds and not bad welds. I think that is the most important single thing that has been suggested in here.

Mr. Llewellyn suggested something. He asked me what would be my feeling about the ductility in the case of a single V weld—how would you determine the ductility of a single V weld on the assumption that you use the sliding scale. My feeling about that would be that if the ductility is different where the top of the weld is stretched than where the bottom is stretched, the extra premium for ductility would be determined by the lower ductility and not the higher. In other words, if bending the sample with the weld outside gives a ductility, for instance, of 150 deg. and bending it the other way gives a ductility of 140 deg., the premium for ductility, if you please, ought to be determined on 140 deg. rather than on 150 deg.

The thing that I really think is the most valuable in this suggestion is the fact that it gives the Boiler Code Committee (and they are entitled to it) some means of knowing that they are going to get good welds. That is the most important thing as I see it, in the suggestion.

The second thing is, I think we are all agreed that a ductile weld, other things being equal, ought to be allowed a higher tensile strength than one which is not ductile. I think we are all agreed on that. Now there may be some practical difficulty in giving a ductile weld the advantage or premium which it ought to have. I will grant

that, but because the difficulty is there is no reason why it shouldn't be done somehow. Understand, there are many ramifications which will have to be worked out before we get the answer, but the main fact is some means ought to be provided so that the inspector and thereby the Boiler Code Committee can be sure they are passing on good welds and not on poor welds.

The second thing is that ductility ought to be given some premium as compared with a weld equally strong from a tensile strength standpoint which is not ductile.

Mr. Hobart: It is only the sliding scale part I don't agree with. You could have the advantages of his suggestion and adopt the limit of 9000 lb. working stress per square inch provided the tensile tests showed not less than so and so much tensile strength and provided the ductility tests showed not less than so and so much ductility, but I don't think one ought to replace one by the other. I don't think the result should be made up of a mixture of ductility and tensile strength, but rather there should be a limit for each and a good weld should not be below either of the limits adopted for tensile strength and ductility. I like his ductility test much better than I like the one usually used.

Chairman Oehler: That is an excellent thought to add to futture discussion.

Mr. Larson: It seems to me there have been a great many very excellent ideas expressed this afternoon in regard to ductility of welds and giving credit for the ductility. As has been suggested milling off or machining off the weld before making a bend test might help in obtaining more uniform results.

Some difficulties in the application of a sliding scale based on the physical properties of the weld have been pointed out, but these can probably be overcome, to a large extent, by rating or grading the manufacturers in a manner similar to that now applied to welders.

I think the variation between welds made by different men at a given plant by a given process is less than the variation between welds made at different plants. For that reason it should be just as feasible to rate manufacturers as it is to rate welders on the basis of qualification tests. On the basis of such a rating the working stresses for each plant can be fixed and the designer will not be left up in the air.

The manufacturer making good welds will be compensated by the saving in material, due to the higher allowable working stresses. In this way recognition can be given for good welding and everybody will not be penalized due to the fact that some manufacturers do not produce good welds.

Mr. Owens: Relative to the question of grading manufacturing plants, this question is now being given some thought by the various inspection bureaus, for instance, it is understood that at least one plant manufacturing welding pressure vessels has a bureau's inspector permanently located at the plant. I am glad that this point was

brought out for there is as much difference between the quality of welding done at various plants as there is between different welders.

Mr. Lincoln: One more word. We all know that electrodes with higher ductilities are coming more and more rapidly on the market. Isn't it fair that the fellow who pays more for his more expensive electrode rod to get the increased ductility should get a premium for it? Is it fair to hold him down to the same tensile strength as the fellow who uses the cheapest stuff he can find? If a fellow is willing to get a more ductile weld at a greater expense, why shouldn't he have some benefit from it? I think that is only fair.

FRIDAY MORNING

April 26, 1929

The Last Technical Session convened at 10.15 a. m., Mr. E. A. Doyle presiding.

Discussion paper on "Production of Ductile Welds in Nickel and Monel Metal,"* by Mr. N. B. Pilling, International Nickel Company.

Mr. N. B. Pilling, The International Nickel Co.: Mr. Chairman and Gentlemen: Since the paper that I am going to give is printed and in your hands, I will not try to read it but just present a few high spots. In considering the welding of nickel it might be proper to consider, first, the difference between welding steel and welding nickel and high nickel content alloys. Viewed in its most elementary sense I suppose one can say that a steel weld should be dependable, strong and perhaps not too expensive. That is boiling it down to a minimum. With nickel and monel metal and other high nickel content alloys, the situation is somewhat different. These metals are expensive metals and when they are used in any particular application, there is a real good reason for it.

Among the reasons for using these high-cost metals I will mention two. One is the ability to retain a high surface finish. Another is its ability to resist corrosion by many common liquids. A weld in these metals must not only fulfill that requirement of the steel weld, be strong and hang together, but it must retain these other properties as well. You should be able to take a weld, dress off the excess and grind or polish it and not have an unsightly surface. Furthermore, such a seam should be quite as resistant to corrosion as the plate metal itself is.

Nickel and these alloys are quite prone to develop defects in welding which are precisely of the kind that you do not want—little cracks or porosities, etc. Fortunately, the situation is cleared by the circumstance that to get around this does not call so much for an extreme degree of individual manual skill on the part of the operator as the

*Paper published in April, 1929, issue of Journal of A.W.S.

adherence to certain precautions which are called forth by the metallurgical requirements.

The International Nickel Company has been well aware of the need for study on this problem and has been actively prosecuting it for a number of years. These developments that I am about to tell you of are not the result of a short period of intensive study but rather represent the culmination of ten years or so of effort which is reflected in the fact that in spite of many assertions to the contrary that you will find in some of the textbooks, statements that are religiously repeated in new editions, stating a great difficulty which is encountered in welding nickel and these alloys, that a very great tonnage of these alloys has been successfully fabricated into equipment which bears testimony to the practical way in which welds can be made. The key to the production of good welds lies in the deposition of metal which is metallurgically sound. Nickel differs from steel in being very sensitive to the conditions under which the metal is melted and perhaps this condition can be summarized in the statement that nickel or any of these high-nickel content alloys as they appear before you as something to be welded, contain a number of highly reactive elements that have to be there if the metal is going to be sound, ductile and strong, yet which are very hard to retain when the metal is melted, especially under oxidizing conditions.

Nickel will absorb carbon very rapidly if it is brought in contact with it when it is melted and excessive carbon will precipitate out like graphite does in cast iron. That spoils it. An excessive content of oxygen, which is also taken up rapidly, will appear as an oxide structure, which is quite brittle also. Those two extremes must be avoided.

In addition, all of these alloys will soak up a tremendous amount of certain gases like carbon monoxide or hydrogen. The metal will be perfectly tranquil when melted, but during the freezing will expel them and a weld made under conditions which allow these to be taken up will look like a piece of sponge cake, very porous and which can be knocked apart by a small tap.

The trick, if you wish to call it that, in welding these alloys, consists in so controlling the conditions of fusion so that the loss of these elements, which include carbon, manganese, magnesium, is avoided. Naturally, the way in which you do that depends on the fusion method which you are using. An oxyacetylene fusion is quite different from an arc fusion.

It has been our intention in this paper to give a series of object lessons showing in the tables samples of nickel and monel metal which have been welded in various ways, and in each of these tables you will find, first, the strength and ductility of the unwelded sheet on which the test were made; again, tension tests of welds made under what you might call poor cond tions or conditions which might easily occur; and, again, welds made under conditions which we consider to be the best that we know of.

We have thought that a tension test is quite good enough to show differences in quality of this kind. You can easily think of more refined methods of test, but the range in quality which it is possible to get in welds of this kind is so great that apparently no greater refinement in testing is required than this.

The tests that we have made might be divided into two groups. In one the excess weld metal was dressed off as much as it could be without digging into the plate. In the other the reinforcement of the weld was left on entirely and the strength of the joint investigated. The first method tells you something about the quality of the weld metal; the second the joint as a whole. All of the metal which is included in these tests is commercial metal, such as you would be confronted with were you welding it.

In the metallic arc method, in which the filler wire serves as one electrode of the arc, the little drop on the end of the electrode, of course, reaches a very high temperature and that temperature is high enough so that the magnesium content for one thing, which is a metal of quite low boiling point, tends not only to oxidize, combine with oxygen and nitrogen, but even to boil out. Welds made in the open air under such conditions are almost certain to be extremely poor in quality, extremely porous and break apart at a very slight stress and are quite useless.

The way to get around that seems to be to provide a suitable protective atmosphere. Hydrogen is not particularly good because the metal will absorb hydrogen and give it off again, but there are some compounds which can be combined into an electrode coating and applied to the filler which will evaporate at the arc temperature and displace the air and provide a harmless atmosphere. One element of that kind is calcium. It is quite possible theoretically to use calcium metal, but a more convenient way is to use one of the cheap alloys of calcium which is stable in the air—calcium silicide, for example. That is brittle and can be ground up to a fine powder.

It is desirable, also, to have some other element of a highly reducing nature that is not volatile, such as titanium, and we have found that a mixture of the two works very well, and a coating of that kind is described in some detail on page 23.

In the table on page 24 you will see the effect of using that coating. With nickel, for example, the weld made with a bare electrode, breaks under a few thousand pounds stress, with a hardly detectable elongation. Using this coating, the strength was about half that of the plate and a very considerable elongation. The same is true of monel metal and examples are given of a couple of coatings of this general type.

In the carbon arc the difference is that the metal dropped on the filler rod does not reach the high temperature that it does when it is situated at the crater of the arc. The weld is made at a lower temperature. We found that using this coating which we described (and it is essential) the welds are even better than with the metallic arc.

For example, you will find nickel welds given which broke under 50,000 lb. stress, the plate metal breaking at 75 and giving a total elongation in 2 in. straddling the weld of nearly 19 per cent.

We have generally found that monel metal is more amenable to welding than nickel, as any departure from conditions that seem to be right for welding shows up sooner with nickel than with monel and in the carbon arc; for example, the best weld that we get using the titanium-calcium electrode coating gives a strength of nearly 58,000 lb. and an elongation of 34 per cent. We are inclined to lay considerable stress on the elongation figures as we have found that the one thing that we require, that is soundness, and secondarily, strength and ductility, are all tied together pretty well. When we get a sound weld we are pretty sure to have one that is strong and also one that is very ductile.

In oxyacetylene welding, the operating temperatures are lower, but there is another condition that is pretty bad. The flame, in some parts of it, is extremely oxidizing. Even when you think of a reducing flame, containing plenty of carbon monoxide, bear in mind that magnesium is oxidized by carbon monoxide. Probably all parts of the oxyacetylene flame are oxidizing toward the one element in nickel that you should do your best to keep in it. Welds made with the oxyacetylene flame under what you might call normal conditions do not look so very good. They are ductile, to be sure, and have around 10 per cent elongation. That is not good compared to what we can get with the other methods, the carbon arc, for example, with 34 per cent elongation. That seems to be due to the absorption of some amount of carbon monoxide and its subsequent precipitation out on freezing. A weld made under normal conditions with oxyacetylene torch will show a columnar structure and rather shiny appearance, indicating that there are voids between the grains in the weld metal, not complete contacts.

Strangely enough a slight change in the rate of freezing of the weld will improve that quite a bit and give these bubbles of carbon monoxide a chance to gravitate out easily. You can check the rate of freezing by turning your torch backward so that the expended gases of the torch flame instead of traveling on ahead of the weld to be made bathe the part that has just been laid down. If you will look in the table you will see that with nickel this change increased the elongation from about 10 per cent to 17 per cent with a corresponding increase in strength. With monel metal the elongation was increased from 8 per cent to about 34 per cent. It is very effective when you can do it. Unfortunately you can't always do it.

A more convenient way of achieving the same end, although by a different means consists in introducing into acetylene a gaseous compound of boron. The boron compound is broken up into boric oxide by the heat of the flame and you have a slightly fluxing constituent present right in the flame itself. The advantage of that is that you can control very closely the proportions of that flux present in the

flame and all that it requires is to use the proper way of introducing the boron into the acetylene.

To revert a moment to the use of fluxes in general, applied externally by painting on a solution it is true enough that the crust of magnesium oxides and other oxides that also form on nickel and these alloys when you weld in the oxyacetylene flame in some cases may be bothersome enough to interfere with the penetration. Fluxes will certainly help that out, but the thing we find is that you can't stand too much flux. If there is enough flux present applied in any way whatsoever to completely flux this coating of oxides on the surface so that you get a mirror-like surface, you can be pretty sure you have gone too far and that the oxidation of these reactive elements is proceeding pretty fast. It is quite possible to take a nickel, for example, which can be made to give excellent welds and make very poor welds out of it simply by fluxing too much.

The use of this gaseous boron compound gets around that difficulty. The amount that is present at the weld is always the same. You can make it right. If you will consult Table III, you will see that the use of borated acetylene gives with nickel an elongation of around 20 per cent compared ith 8 per cent made by the ordinary methods of oxyacetylene welding. The difference with monel metal is 8 and 34 per cent.

Introducing a gaseous boron compound into acetylene isn't as hard as it sounds. That seems like a trick but it can be done very easily. All you need to do is bubble the acetylene through a solution containing a volatile boron compound and fortunately the volatile boron compound can be made up out of drug store chemicals. Denatured alcohol, boric oxide or fused boric acid give a solution of ethyl borate, which is a compound in the pure state boiling at below the boiling point of water, I believe. A solution of this contains a portion of this borate and in just about the right amount to impart the correct proportion of boron to the oxyacetylene flame.

One thing that occasionally may bother one in making welds in nickel or monel is the cracking of a weld. There is one point I want to mention here and that is that both of these metals at a temperature just below the freezing point (that is, the temperature of the rim of the freezing pool of metal) are extremely brittle and if put under load will break at once. When you have made a weld and are starting to reweld it, the plate, of course, is expanding due to the thermal stress of the heat going in. This little rim of metal right at the edge of the plate, of course, is bearing all of the stress on one side of the puddle and it breaks. As you proceed to make the weld across the plate, the crack follows spontaneously and you finish with a weld that is completely broken in two.

There is an easy way of getting around that by simply taking the precaution to start any re-fusion of that kind an inch or two away from the open edge so there is an inch or so of cold metal to bear the tensile load. That works in many cases.

In Table IV are given the strengths and elongations of these three types of welds, metallic arc, carbon arc and oxyacetylene, made by what we believe to be the best methods. The strength is compared with the strength of the normal plate and you will see there is no difficulty at all in getting welds which are anywhere from 90 to 95 per cent of the strength of the plate metal. The reason you do not get a full 100 per cent joint efficiency with a reinforced weld is due to the fact that nickel and these alloys differ from steel. When you heat steel the grain may be refined at the critical temperature. With nickel, once a coarse grain is developed (and it always does next to the weld) it is there to stay. That is always softer and weaker than the rolled and fine grained plate material.

Just to summarize the whole business you might say that both nickel and monel metal are excellently adapted for fabrication by fusion welding methods. The production of welds which are strong, sound and ductile, requires adherence to suitable methods of welding rather than the exercise of a high degree of manual skill.

Chairman E. A. Doyle, Linde Air Products Co.: I think everybody will agree that we have heard about the most illuminating paper on the welding of nickel and monel metal that has been published so far. Surely there must be some questions that some of those present want to ask. Everybody who has any welding to do and comes in contact with nickel and monel has some problem. I know you are not bashful and we would like to have some discussion on Mr. Pilling's paper.

Mr. W. B. Miller, Union Carbide & Carbon Res. Labs.: I wish to congratulate you on your excellent paper, Mr. Pilling. Our work checks yours on starting 1 in. from the end. This is an excellent practice on practically all sheet metal welding, and the French dwell on it in several of their brochures on welding practice.

On page 21 Mr. Pilling calls attention to our recommendations of the bend test for weld ductility, remarking that he has found the simple tension test to give adequate ductility figures. Looking at Table IV, he shows very uniform per cent elongation in 2 in. over the weld. Offhand, this looks to me as though that is probably 90 per cent plate ductility. Since the welds are reinforced and the plate is $\frac{1}{8}$ in. thick, there will be about $\frac{1}{4}$ in. to $\frac{3}{8}$ in. wide weld in a total gage length of 2 in. Therefore, the per cent elongation in Table IV appears to be plate metal elongation. The summary states that the three methods of welding give dissimilar weld metal qualities, which would seem to bear out this idea that this is plate ductility because the dissimilar quality welds all yield the same elongation in 2 in. over the weld.

I should like to ask Mr. Pilling in the number of test specimens that broke outside of the weld, if the fracture occurred immediately adjacent or say a $\frac{1}{2}$ in. to 1 in. away from the weld. That would depend somewhat on the width of your specimens compared to the thickness, but I would like to know if any of the coupons broke just at the edge of the weld metal.

Mr. Pilling: Mr. Miller is entirely right in what he says. To take

up his first point, our remarks on bend test were not derogatory at all. What we mean is that for our own problem we find the straight tension test to tell us all that we think we need to know. Perhaps in some of the other metals he worked with, that is not the case.

He is also quite right in assuming that the 34 per cent elongation, for example, given in Table IV, is largely made up of the extension in weld metal. We have not tried at all to measure the ductility of the weld metal itself. When we have a poor weld, that is a very porous weld and it is broken in tension, you will find that the actual load-bearing area in the weld is quite small, due to the loss of cross-section due to holes. That means the actual stress intensity in the weld itself may be high, although the applied load is small. Then, as the tension test proceeds, there is a very small length within the weld that is actually at the yieldpoint and above and is stretching. If you had an extensometer or a gagemark small enough to straddle a single bubble within the weld, you would probably find that it had the normal ductility of monel metal. The elongation which you would get in 2 in. across the weld, however, would be almost negligible.

We feel that we have a good weld when the weld metal is so sound and strong that during a tension test the maximum stress intensity within the weld is not much greater than that in the plate thus forcing the adjacent plate metal to share in the stretching.

Mr Kihlgren has a number of tension test pieces mounted on a board showing the actual location of the break. I think you will find that it is usually ½ in. or so away from the weld when it breaks outside. These test specimens that he has have also had a part of the weld metal ground off and polished and if you take a look at them you will see in the case of these welds which are strong, how sound the inside of the weld is. There is also on this board a little object lesson consisting of two metallic arc welds, one of which is made in the open air without any coating, and the other with a coating that we recommend. In the one case, the weld could be flattened over (the same nickel in both cases), and the other was so brittle that it split apart under the stress of shearing, trying to cut it out of the plate.

Mr. Miller: At the Lehigh University welding symposium, Bethlehem, Pa., Mr. Alexander of the General Electric Company, had some hydrogen sheathed carbon arc welds in nickel and monel metal, and they seemed exceedingly dense and of good quality. He had no physical tests to show, so I do not know what their inside density or their strength would be, but they appeared excellent.

Mr. Pilling: How did you say they were made?

Mr. Miller: He probably used dissociated ammonia for his sheathing gas. They were made, using a single carbon pencil, the base metal being the other electrode. They appeared very dense, so in that case hydrogen didn't seem to produce visible porosity.

Mr. Pilling: My experience with hydrogen is partly in making fusions in furnaces under a hydrogen atmosphere, which is very bad, and also in part with some tests which I have seen made of atomic

hydrogen welds on nickel. Those were not particularly good. Using our ductility index, they would be rated rather inferior.

Another thing we noticed with the atomic hydrogen is that the electrodes are of tungsten and bits of tungsten appear in a nickel weld. Since welded joints are apt to be submerged for corrosion-resisting surfaces, we don't like to see specks of tungsten.

Mr. Lincoln: It strikes me the only way in which the actual ductility of a weld can be made is by bending the weld so that the stretch actually comes in the welded metal. By bending the welded sample around a bar placed at right angles to the weld, the stretch has got to come in the welded metal and if it is possible to measure that stretch, you get a fairly close picture of the ductility.

I happen to have done some work with the shielded carbon arc. With this work steam was introduced into the space around the arc. This steam reacted with the hot carbon according to formula C plus H_2O equals CO plus H_2. Both CO and H_2 are strength reducing agents, therefore, make the atmosphere around the arc quite strongly reducing.

There is a further reaction between the hydrogen according to the reaction above, and the hot carbon which produces some sort of a hydro-carbon gas. The presence of this hydro-carbon gas in the space around the arc is evident by the yellow flame which results when the gas from the space around the arc escaped and was ignited.

It is quite possible that the results which Mr. Miller states Mr. Alexander obtained and the results which you obtained with a pure hydrogen atmosphere are due to the fact, in Mr. Alexander's case, that the atmosphere wasn't entirely pure hydrogen, but it had some of the hydro-carbon gas which may have made some difference in the results.

Chairman Doyle: It is really in the way of discussion that we bring out the best points of the paper and value to the balance of the Society.

Mr. Little: I was quite fascinated by Mr. Pilling's use of this borated acetylene, and I would like to ask him if he tried acetylene just with alcohol and no boric compound dissolved in it.

Mr. Pilling: Yes, we have. That thought occurred to us, too. It is possible by using a rather different borating solution than the one we described to get so much of the boron compound in the acetylene that you can actually get a deposit of boric oxide in beads along the sides of the weld.

Mr. Larson: I would just like to ask Mr. Pilling if he has done any work with steel containing rather high amounts of nickel, that is around 10 per cent.

Mr. Pilling: No. Mr. McKay, though, is present. Possibly he can say.

Mr. R. J. McKay, International Nickel Co.: Do you mean welds of straight nickel steel or nickel chromium steel?

Mr. **Larson:** Straight nickel.

Mr. **McKay:** I don't know of any experience where we would use such a steel. I don't know where such steel is used, as a matter of fact; unless Mr. Pilling has some experience in the laboratory. We haven't any.

Chairman Doyle: As there doesn't seem to be any further discussion, we are going to thank Mr. Pilling and the International Nickel Company. I believe I may take the liberty of saying for Mr. Pilling that if any of you get into difficulty in the welding of either nickel or monel, you will find both himself and his company more than glad to give you the help that they have extended to every one that I have ever known to apply to them for it.

Discussion Paper on "Welding of Pressure Vessels for High Temperature and Pressures,"* by T. McLean Jasper, of the A. O. Smith Corporation.

Mr. **Miller:** I would like to ask Mr. Jasper what grade of steel they use and the carbon content particularly, and if, in these large vessels, the main mill rolling direction of the plate is in the long direction of the vessel. In the vessels tested to destruction, the fractures were exceedingly straight, and I want to know if the direction of these fractures was in the mill rolling direction of the plate.

Mr. **T. McL. Jasper,** A. O. Smith Corp.: In some of the test vessels the direction of rolling is parallel with the axis of the vessel. In others it is the other way, the ring type, the maximum stress comes parallel with the direction of rolling. We have made quite a number of tests on the strength of steel in both directions, especially in the thick materials, and we find that the strength of the steel in either direction varies very little indeed. The ductility is the thing that varies with the direction of rolling in steel.

In the first vessel that you saw, which is a very straight fracture, the direction of the rolling was the same as that of the fracture. In the other vessels, the fracture was not straight, although the direction of rolling of the steel was the same. The tendency is for the fracture to keep in the same straight line when once it starts, no matter whether you have maximum stress in the direction of rolling or at right angles to it. We have tested about eight large size vessels now, both types of construction, and that is brought out in both types.

With reference to the quality of our steel, the steel we use for pressure vessel work is made by the Lukens Company, and right off the bat we ask for 50 per cent cropping, before any metal comes to us. Then it undergoes a very severe inspection in addition. During the last year an average utilization of steel that was melted for us was about 41 per cent. We use 20-30 carbon, fairly high manganese, low sulphur and phosphorus in our steel.

I might add this: We weld the steel up to almost any strength that we might use.

Mr. **Lincoln:** The curve Mr. Jasper showed on the screen showing

*Paper published in June, 1929, issue of Journal of A.W.S.

the higher ductility and especially the higher proportional limit was very interesting. I should judge from that the material that went into the weld (in other words, the weld metal) was of somewhat different material in some respects than the original plate metal. I would like to know if Mr. Jasper will tell us in what respect the weld metal differs from the plate metal so that he gets that improved proportional limit.

Mr. Jasper: You are asking me, of course, what weld rods we use and that is a matter we avoid telling, because it is one of the things that we have spent tremendous amounts of money in finding out, and, therefore, if I seem not to answer that question as it has been put, I trust you will bear with me. On the other hand, let me give you a picture of why the weld is improved. It is because of the heat treating effect in the process of welding, and that is simply a matter of studying the physics of your arc, understanding how it works.

I would say this: our welded metal as deposited is practically no different from the plate metal, except that it is cleaner. To indicate the value of this quality in the weld of those two vessels, they had been in service for over three years; there were no places adjacent to the welds where corrosion had decreased the thickness in the weld over what it had done in the plate. As a matter of fact, the weld stood out in relief, showing that the corrosion attack on the weld is less rapid than on the plate.

The second vessel that was shown had corroded from the original thickness of two and a half inches to one and six-tenths inches in thickness. There has been enough time to show whether or not the weld would corrode more rapidly or less rapidly than the plate material.

You must understand that those vessels were in a service under very high temperature and under a corrosion condition which may be very severe. Some of the oils which are used for cracking are very corrosive. We had from the West Coast an actual measurement of corrosion which represented three-quarters of an inch of steel per year in vessel wall. I am not in a position to tell you what kind of steel was used in this case, because I do not know, but that is the rate of corrosion obtained in some of the cracking units which are being used today.

Mr. Owens: We are indebted this morning to Mr. Jasper, of the A. O. Smith Corporation, for a very valuable contribution. To me it shows what can be accomplished in our welding development by a thorough scientific study and procedure control. This is what the industry has been striving for, and the A. O. Smith Corporation has spent a considerable sum of money in order to obtain it.

A few days ago I was at the Watertown Arsenal to look into the question of the X-raying of welds. Some years ago I did some work along this line when connected with the Navy, but circumstances developed which prevented me from following it up. What I saw in the Arsenal when based upon my previous experience, clearly indicates to me that a field for analysis of welds is opened up by the

use of the X-ray. Its principal use lies in the perfecting of a process and its technic by the X-raying of small weld specimens. If sample welds are made during the manufacture of pressure welds, then the X-raying of these welds will indicate the soundness of the weld in the vessel. It might even be possible to X-ray a few welds on a structural job as it goes through the job.

I believe it is generally thought that X-ray equipment for material up to 3 in. thick, similar to that used at the Arsenal is very expensive. However, I was informed that such equipment, including the lead lining of the room, but exclusive of the room itself, will only cost between $8,000 and $9,000, I believe that any company doing important research work on welding can well afford to spend this amount so as to perfect their technic. I leave this suggestion with you with the hope that the X-ray will assist in obtaining welds of the character described by Mr. Jasper.

Mr. Jasper: I would like to add a word here. Of course, these vessels are very large and some of them are over 80-ft. long, and they have to be handled by heavy cranes. I think what Mr. Owens has in mind is that the process development of the thing shall be watched by using X-Rays. I question if we could put in enough equipment in our plant to serve the every-day welding that has to be done, because it would take so long. As I understand it (I may be wrong), it takes quite a while to penetrate through the thicknesses we are speaking of. In order to perfect your process, you may work on small specimens, and therefore in that case it will not be objectionable to use X-Ray. The application to pressure vessels that are being built, say one, two or three a day, of the size shown you, would mean a tremendous equipment of X-Ray to explore each weld. I wonder if you see how much equipment it would mean and the necessary precautions it would involve so that the X-Ray would not endanger anybody in the operation of it.

Mr. Owens: What I meant was that the X-Ray is a very valuable tool for the development of our various welding processes. Once having perfected the technic, it will not be necessary to X-Ray every foot of the joint.

Mr. R. K. Hopkins, M. W. Kellogg Co.: Referring to those curves showing the proportional limit and ultimate strength, I would like to ask Mr. Jasper what the ductility was through the weld.

Mr. Jasper: The minimum ductility through the weld was 20 per cent elongation in 2 in. We have had ductilities running quite a little higher and in some of our tests we have had ductilities running down lower, but the minimum ductility we get with all deposited weld metal is around 18 to 20 per cent elongation in 2 in. This is obtained in production welding. These things that you saw twisted up, were taken out of part of a vessel.

Mr. Anderson: I would like to ask Prof. Jasper if he can give us some idea of the relative cost per pound of deposited metal under this process after the technique has been developd. How does an oxide and nitrate free weld with practical freedom from blow holes and gas pockets compare in cost per pound of deposited metal with the

commonly reported figures for welds that don't achieve such high quality?

Mr. Jasper: I am not at all familiar with the matter of cost. I am particularly kept away from the question of costs in our plant. I am supposed to consider only quality, and not to bother about cost. I also avoid any discussion of cost or any inquiry as to cost, and am not able to present those data to the gentleman who has just spoken. I don't see any reason why the cost should be any greater in depositing clean metal than it is to deposit it dirty. I would think it would be more costly to deposit it the dirty way, I don't know.

President Llewellyn: Might I add one word on the question that was put by Mr. Owens and answered by Mr. Jasper? It is, of course, along the line about which we hear so much, namely the determination of the soundness of every weld that is commercially put out. We are familiar with a great many methods for determining soundness, X-Ray, magnetic variation, and a number of others. They are all good, but from a rigorous standpoint, I am convinced that it is no more possible to determine the absolute soundness of each specific portion of a weld than it is possible to determine the extent to which each specific rivet fills the hole. Conversely, it is just as possible to do the one as to do the other.

I didn't say that it is not possible to determine whether the head of an individual rivet rings true. Every one who has had experience with rivets knows that it is entirely feasible for a good riveter to make a poor rivet resonant in sound, but that each and every rivet in a large member, such as a pressure vessel, fills the hole to the same extent is not to be expected. We have confidence in the rivet, and rightly so, but that is not because the inspector's hammer rings true. No. It is because we have used them for 40 years with satisfactory results.

I remember when the standard specifications for riveted structures contained a clause like this: Shop rivets shall be given a unit value in shear and bearing of so much. Field rivets shall be given values of two-thirds as much.

Look through the specifications today and you will not find that clause. You will find a clause that reads like this: Machine-driven rivets shall be given values of so much. Hand-driven rivets shall be given values two-thirds as much.

We have acquired confidence in the machine-driven rivet, not because each and every rivet fills the hole to exactly the same extent, but because we have used them with satisfaction. Confidence in welding has got to grow along similar lines, and it is only by the excellent development work, such as has been described to you this morning by Mr. Jasper and the other speakers that such confidence can be acquired.

Mr. Jasper: This brings up a very important point, and I am in great sympathy with Mr. Llewellyn, particularly because he stresses the point that we must have confidence. My thought with reference to the application of welding to industry is this: We can carry our

procedure control and all the other things recommended as far as possible, and at the end when we have the vessel built, then is when we should make the test of the weld, on each weld, each foot of it, by a severe test of the vessel.

If, on the other hand, we don't start with severe testing of welds, vessels that are welded, then we are going to lose this thing which will bring us the confidence that we want. It is going to take time for us to get that confidence. It is going to come quicker if we test our vessels severely. It is quite true we are never going to be able to inspect the production welds by the use of X-Ray. I am hoping that we may be able to inspect them by the use of the electric method that Mr. Sperry has developed for his transverse fissures, but even so, I believe that the severe test is the best thing that we have to keep us from going astray.

Mr. **W. L. Warner,** General Electric Co.: I would like to ask Mr. Jasper, in connection with his endurance tests—he has shown pictures and results of endurance or fatigue tests made in the direction parallel to the weld—if he has made similar tests at right angles to the weld, and if so, if there is any difference.

Mr. **Jasper:** Yes, sir, we have made tests in both directions. When you make tests across the direction of the weld and you have the center of the weld in the middle of a curved specimen, then, of course, your maximum stress comes in the center of the weld. We have not only done that, but we have taken the metal adjacent to the weld, with results similar to the one I showed you for the static testing. In other words, whether it is across the weld or with the weld, it makes no difference. The fatigue strength is greater for the weld metal than for that of the plate.

Mr. **Crowe:** I think it was in the second slide of the tensile specimens he showed the effect of heat on both the proportional limit and ultimate strength, and the ultimate goes off into a straight line on either side of the maximum, but the proportional limit showed a dropping. Is that typical of all the tests?

Mr. **Jasper:** No, it is not typical, and I put this down directly to the effect of overheating the metal by burning it in cutting the piece from the original slab, and not having all the burnt metal eliminated.

Mr. **Crowe:** Wouldn't you rather expect that to affect the ultimate as well as the proportional?

Mr. **Jasper:** Well, it doesn't seem to have here. I have been asked that question about three times now, and that has made me go into a study of it very carefully. We do know that the apparent yield point is affected a good deal by heat treatment, and we do know that the apparent yield point is affected a good deal by overheating. In the making of these vessels, we take great pains to machine off all burnt surfaces in order to remove this undesirable material. I believe it is a very proper thing to do. These test specimens are far enough away from the weld so that we have to attribute it to the steel; we can't attribute it to anything else, because they all broke in the steel.

Mr. R. M. Allen, American Car & Foundry Co.: I would like to ask if any impact tests were made similar to the fatigue and tensile tests and if so what the results were.

Mr. Jasper: Yes, we have made test results of impact. You may have seen slides that I presented at other times. We find that the energy of rupture is higher in the weld deposit than it is in the plate. You also find that the weld metal is very much more free from impurities which, I believe, is largely responsible for this.

Chairman Doyle: Gentlemen, I believe we could go on for the balance of the day on this most interesting subject and ask Mr. Jasper continued questions which he has so willingly and intelligently answered for us, but the time is getting short, and I am not going to ask for any more criticism.

I would like to say just one word before we pass on to the next speaker, and that is that I believe we are all going out of here this morning feeling proud of ourselves for being either a part of or associated with an industry as young as the welding industry, that will allow a man of Mr. Jasper's caliber and knowledge to stand up and tell us that we can produce anything 100 per cent, and not only tell us, but be able to prove it. I want to thank Mr. Jasper again for what he has told us.

Mr. Male: I would like to just put before the Society at this time a point of view of the student at the technical college. I am down here from M. I. T. to attend the meetings of the Society, and I brought down with me one particular idea that I would like to convey to you. About five weeks ago I attended a supper-meeting of the American Society of Civil Engineers, Student Chapter, at Tech. After the supper was served, there was a series of films shown to us that were sent down by a firm that manufactured pneumatic riveters. The occasion was quite a propitious one. There was a group of 125 students at the meeting. The showing of that series of pictures was preceded by one showing the drilling of the Cascade Tunnel, a film that very ably showed the men something of that engineering feat. When the pictures of the riveting came up, there seemed to be quite a series of diverse applications that it treated, all of which seemed to hit at one particular idea.

There was a picture of a bridge in Chicago, a lift bridge, that was shown, and several shots were shown of the multitudinous rivets in and about the structure, and the closing line on that particular view was that "When lives are in jeopardy, rivet!" There were several other pictures along the same line.

After the meeting broke up, there seemed to be quite a bit of discussion among the students there as to the particular reason for stressing the importance, at that time, of riveting. I can well imagine that if that same picture had been shown about five years ago, there would have been no particular reason for the stressing of that particular point, because it was a thing that was then fairly well known to every one, and every one was riveting.

The next Thursday, after that Tuesday meeting, there wasn't a

piece of welding literature to be had in the library on call. Most of the students there seemed to want to know what had been developing to cause such very strong propaganda to come out in favor of riveting.

In the curricula in both architectural engineering and in civil engineering, and in most every other engineering that deals with either stationary or moving structures, riveting is, of course, a very serious problem to the students. They have got to know all there is about it. No one up to within the last four or five years that laid claim to the title of an engineer called himself a structural *riveting* engineer. When he assumed the title of engineer, he was supposed to know what was necessary to build his structures. Today there seems to be, I think, a rather unfortunate tendency for any one who has at all mastered the art of welding design, as far as the art is known today, at least, to call himself a structural welding engineer which, I think, is rather unfortunate, because, as I said, a man who intends to assume the rôle of an engineer should know what is necessary of the fundamentals, whether it be in the application of riveting or in welding.

The point of view that the students up at the school have taken (and I think that it is not confined exclusively to Tech, but is rather widespread around the country)—is an attitude of open-minded eagerness to learn about welding, a lot of the professors at different institutions are doing research work on welding either in cooperation with the Society here or independently, and the work that they have been doing has been disseminated throughout the institutions with which they are connected, and the students have been becoming used to changing ideas rather rapidly. I know that in the particular course that I am taking now, within the next two years there is going to be given a more or less fundamental discussion of welding together with that of riveting. We have been studying rivet groups, and stresses in rivets, and the ultimate stress in the furthermost rivet from the center of gravity, for a good number of years, but with the coming of a different point of view, there will also be in parallel with the work we are taking up a tendency to look into the possibilities very broadly offered by the welder.

Whether the interest that is shown will culminate in the forming of student chapters of the American Welding Society or whether each particular Society there, whether Civil Engineers, or Mechanical, or Electrical Engineers, will within their own groups form such interested groups as will help to further spread the knowledge, I don't know, but I can say this, that the work the Society is doing and doing so ably, to help educate the people of the country to accept the idea of welding, is constructive work, and is bound to bear fruit.

Chairman Doyle: I guess this is about the first time we have ever had the pleasure of having a member of a student body tell us that student bodies really want welding information. I hope that as a result of this little talk we have had this morning everybody will, especially the producers of equipment, electric or gas, lend a helping hand toward the dissemination of information to the schools. A great deal of that work is being done now. More could be done.

Welding in the Chemical and Process Industries*

By A. G. WIKOFF†

THAT the chemical and process industries are taking advantage of the opportunities offered by welded construction is evident even without actually visiting various plants and making a detailed survey of applications. The advertising and editorial pages of modern technical periodicals present an authentic and accurate picture of the current trend in the industries that they cover. Study of current issues of the technical magazines devoted to the chemical and process industries reveals a surprisingly large number of references to welded construction. Equipment manufacturers stress the fact that their products are welded, others announce that they are prepared to fabricate welded equipment to specification. In addition, announcements of the special metals and alloys developed to resist the effects of corrosion and high temperatures almost invariably include a statement as to weldability in discussing their properties. Aside from direct references to welding in the editorial page, an examination of the illustrations will also reveal the extent to which welding is being used.

The reason is evident from a consideration of operating conditions in these industries. In no other field are the materials of construction subjected to such severe service conditions. They must resist the effect of acids, alkalies, corrosive salts, mixtures, as well as gases and solid materials of all types. Liquid air and the electric furnace represent the extremes of temperature to which these materials may be subjected. The pressure under which processing must be carried out also varies widely. In some cases the equipment must maintain a vacuum of only a few millimeters, while other equipment will be required to resist pressures of several hundred pounds per square inch, or even higher. In some processes the effects of corrosion, high temperature and high pressure occur simultaneously and present an extremely difficult problem for the designers of equipment.

Practically all of the commoner metals and alloys are found in use at one point or another in the chemical industries. As these fail to satisfy all the requirements, continual investigation is being made to develop new alloys having superior properties, particularly with regard to resistance to corrosion and high temperatures.

It should be remembered that the materials handled in the process industries are all relatively valuable. This means that even a slight leak may quickly result in a considerable loss. In addition many of the materials are of such nature that leakage is most undesirable, quite aside from the question of loss involved. This is the case with such materials as flammable gases and liquids and materials that are of a poisonous or physiologically injurious character.

*Paper presented at Annual Meeting, A. W. S., April, 1929.
†The Linde Air Products Co., New York, N. Y.

From this brief consideration of operating conditions, it is evident that the chemical industries have urgent need for a method of construction that will give a joint permanently tight and leakproof under all operating conditions and one that can be used satisfactorily with all metals, including the newer special alloys. Welding affords such a method of construction and it is consequently being used to an increasing extent in the chemical and process industries.

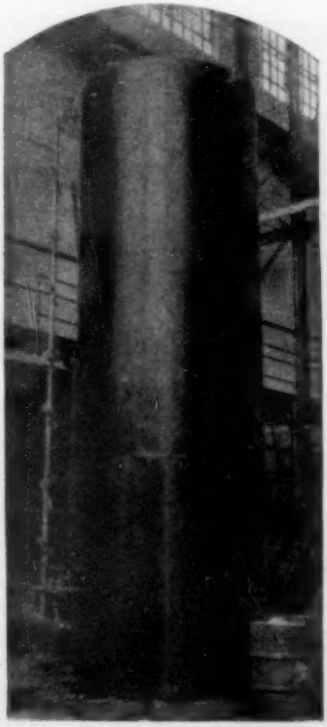

FIG. 1. ENAMELED-LINED STORAGE TANK

The various ways in which a chemical plant can utilize welded construction and apply the oxy-acetylene welding and cutting process to advantage may be grouped as follows:

A—Purchase of standard equipment of welded construction.
B—Special equipment designed in the plant and fabricated to specification by outside manufacturers.
C—Equipment, piping and accessories fabricated by the plant welding department.
D—Maintenance and repair.
E—Demolition.
F—Equipment for small scale development work.

It is obvious that the maximum advantage of welded construction can be obtained only where there is a definite degree of welded-mindedness

among those responsible for plant construction and operation. The chemical engineers responsible for design of plant equipment should be thoroughly familiar with the principles of welded design and sufficiently familiar with welding practice to know that their designs will be in accordance with correct welding procedure. There should also be a welding shop or department capable of handling many of the construction details such as piping and also of taking care of general maintenance

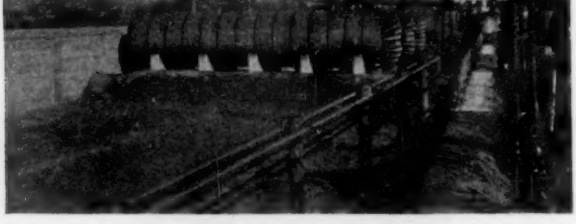

FIG. 2. BATTERY OF WELDED PRESSURE VESSELS

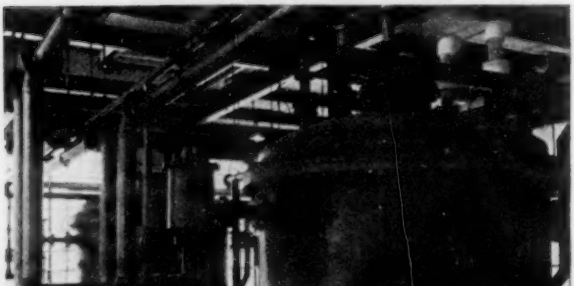

FIG. 3. ABSORBERS, 8 FT. IN DIAMETER AND 40 FT. HIGH

and repair work. Starting with a small nucleus of experienced welders it is possible to build up an organization capable of handling a remarkable variety of work. Of necessity welders in chemical plants will have to be skilled in handling the many different metals and alloys used.

Standard Welded Equipment

At the present time a wide variety of standard chemical equipment is of welded construction. For the processing, storage and transportation of food products, pharmaceuticals and fine chemicals that would be contaminated by contact with metal, enamel-lined equipment is extensively used. The steel base to which the vitreous enamel is fused is fabricated

with oxy-acetylene welded joints because this type of joint will take the enamel successfully.

Other standard equipment of welded construction includes heat exchangers; condensers; stills and jacketed kettles including those of copper, nickel and monel metal; indirect heating systems using circulation of hot oil; jacketed piping; storage tanks, drums and shipping containers of various types.

Special Equipment

The chemical engineering industries require much special equipment designed by the plant engineers in charge of such work. Some of this

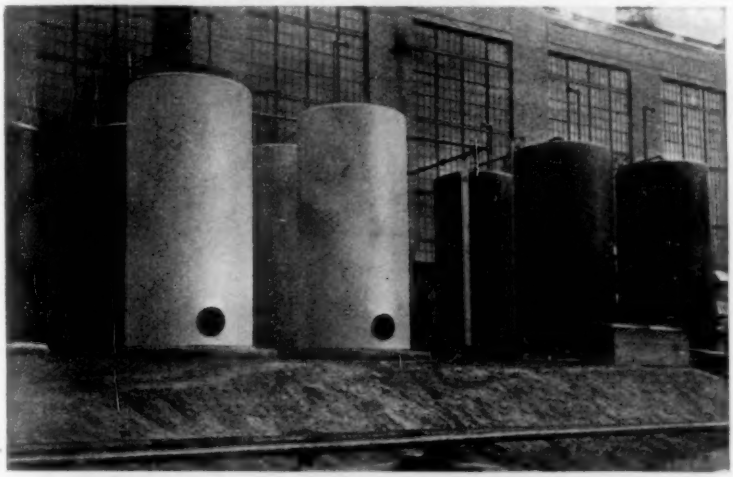

FIG. 4. LOW PRESSURE STORAGE TANKS

equipment can be fabricated in the plant shops but a great deal of it will have to be ordered from outside manufacturers.

Efficient design for welding in chemical plants requires thorough consideration of operating conditions. For example, the ideal design for welded piping to carry chemical products would specify that every possible joint be welded, making the system practically one-piece construction. There are many practical considerations, however, which make it necessary to modify this ideal design. In many cases it is necessary to clean out lines at regular intervals. In other cases, the lines may carry flammable gases or liquids so that the ordinary method of using the blowpipe to make changes or replacements is not possible. Under such circumstances it is advisable to make up the welded line in sections which are joined with flanges.

The same consideration must be given in designing special equipment. Storage tanks can, of course, be welded throughout and the necessary manhole openings and outlets welded into the shell of the tank. Much chemical equipment, however, contains internal parts which may have to be removed for repair or replacement. In developing the welded design

for such equipment, care should be taken to limit individual sections to a size that can be readily handled in the plant in case it should be necessary to remove internal parts for repair or replacement.

In designing special equipment the plant chemical engineer may require the services of a capable welding engineer in order to make certain that his designs are practicable from the standpoint of the fabricating shop.

FIG. 5. ALUMINUM HEATING COIL FOR STILL

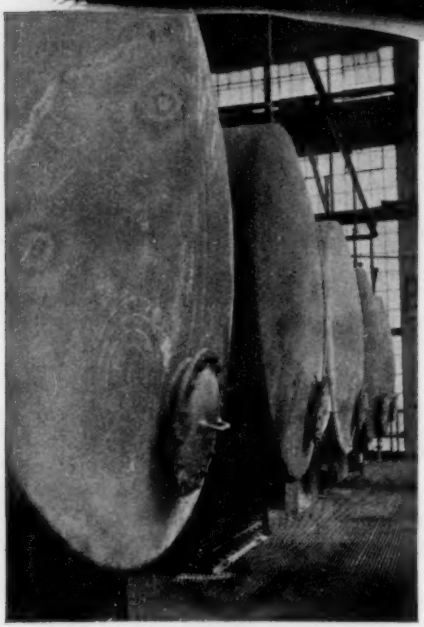

FIG. 6. STORAGE TANKS 10 FT. IN DIAMETER

An example of this is found in the pressure vessels that have been built during the past few years. The problem was to provide safe storage for large volumes of certain materials at pressures up to 300 lb. per sq. in. Oxy-acetylene welded construction was the solution of this problem and procedure controls for welding were developed which made it possible to specify and obtain such pressure vessels. One

group of plants has already installed more than 200 oxy-acetylene welded pressure vessels all of which have proved to be perfectly satisfactory under operating conditions.

Oxy-acetylene welded construction is also being used for a wide variety of process equipment. Among these are absorbers, condensers,

FIG. 7 (ABOVE). 30-IN. WELDED WATER MAIN

FIG. 8 (LEFT) GROUP OF WELDED PROCESS LINES AND STEAM MAIN

including some designed for pressures as high as 600 lb. per sq. in., stills, autoclaves, scrubbers and fractionating columns. Various concerns are prepared to fabricate welded equipment from aluminum, copper, nickel, monel metal, heat- and corrosion-resistant alloys and other special alloys.

In designing an exhaust steam header for a group of compressors in

a chemical plant, welded construction was specified with the result that the entire header was fabricated and shipped as a single piece 56 ft. long. This affords a splendid example of the simplification of design and installation that is possible.

Equipment Fabricated at the Plant

In order to take full advantage of welded construction a plant welding shop or department is essential. With the exception of special equipment, much of the construction work can be done by the plant welders. In a large chemical plant there are many miles of piping systems

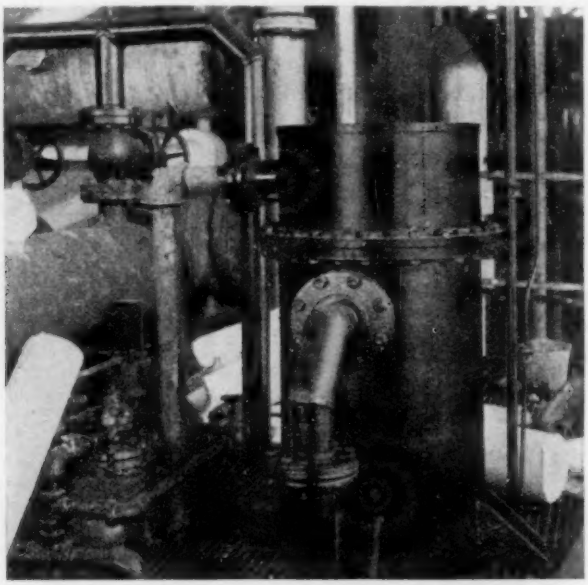

FIG. 9. NOVEL CONDENSER ARRANGEMENT

connecting the various pieces of equipment and the installation of all these lines can be handled by the plant welders.

At one large chemical plant where some of the buildings are located on an island, it was necessary to carry a number of process lines together with main steam and water supply across a bridge connecting the island with the main portion of the plant. The 30-in. water main, 6-in. high pressure steam line and about a dozen small process lines were all welded.

As in other industries, a special feature of welded piping is the ease with which special fittings can be fabricated from standard pipe. This is particularly important in chemical plant work as the piping is of necessity very complicated. As an example, it was necessary to connect three large welded absorbers so that they could be operated in various combinations of series or parallel connections. The special fittings necessary were easily made by the welding shop. Other points where welded construction has greatly simplified piping are found in connection with

special compressor installations and in the control boards for operating various types of equipment.

The welding department can also fabricate the various headers, coils, scrubbers, traps, drips and similar items that are required in large numbers at every chemical plant.

One item that has been found useful is a welded gauge column for use on storage tanks. This column is so designed that standard length gauge glasses can be used.

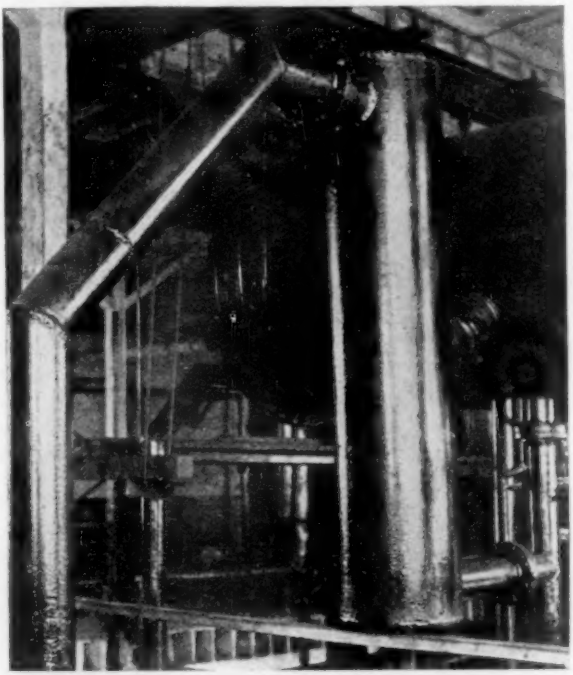

FIG. 10. WELDED CONNECTIONS TO VACUUM EVAPORATOR

Another modification of ordinary practice that has been found useful is to place a standard tubular condenser with the tubes vertical, the uppermost head is then removed and replaced with a welded flanged section of pipe to which an overflow outlet has been welded. Water enters the condenser at the bottom, rises through the tubes and overflows through the outlet pipe. As the upper end is open at all times the tubes can be cleaned quickly and easily.

For high temperature work the newer nickel-chromium alloys are being extensively used and the welding shop should be able to handle these in various forms. Welds in these special alloys operating continuously at temperatures above a red heat are striking proof of the fact that a properly made weld is not affected by high temperature.

In addition to work on equipment and piping the welding shop can also fabricate a large variety of what might be termed accessories. These include supports for tanks and coils, pipe brackets, pipe supports and hand rails.

Lead is used extensively in many chemical plants, particularly those manufacturing sulphuric acid. Much of this work is done by skilled lead burners using the oxy-hydrogen flame. In certain branches of the industry, however, the oxy-acetylene welders are required to handle lead

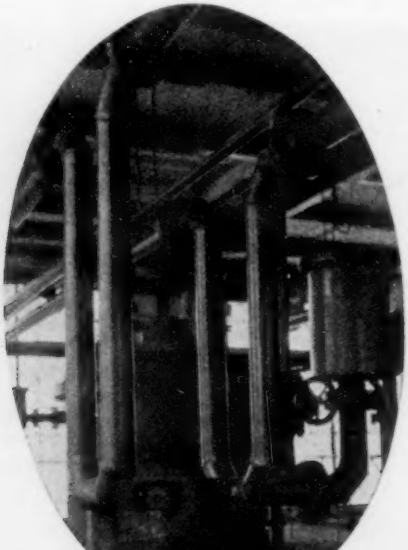

FIG. 11. INTRICATE SPECIALS ARE EASILY MADE

as part of their regular work. In several large paper and pulp mills, the welders have become very expert in fabricating flanged lead piping and special fittings used for handling sulphur dioxide and for constructing the blow-off lines from the sulphite digesters.

Maintenance and Repair

Owing to the severe operating conditions in the chemical industries, maintenance is a serious problem. Where breakage occurs, repair is handled by the welding shop wherever possible just as is done in other industries. Occasionally special problems arise that are of unusual interest. For example, in handling certain very corrosive chemicals, glass tubing has to be used in constructing condensers. In emergency, breaks in this glass condenser tubing have been repaired with the oxy-acetylene flame.

In considering the question of repair it should be remembered that the use of open flames is prohibited in certain sections of many chemical

plants, particularly petroleum refineries, natural gasoline plants, manufactured gas plants, and those producing certain organic chemicals. Cutting or welding blowpipes should never be used in such locations without first obtaining approval of someone in authority who has been designated to pass upon such questions. Tanks, drums or other containers that may have held flammable liquids or acids should receive thorough cleaning before any attempt is made to cut or weld. Wherever possible the work should be done while the container is full of water.

In this connection it is interesting to note that there has recently been placed on the market a portable device for detecting the presence of certain gases and of indicating whether or not they are present in concentrations which form explosive mixtures with air. The use of such a device before welding or cutting in any suspected location would seem to be a sensible safety precaution.

Demolition

Chemical processes are constantly changing particularly in certain branches of the industry and as a result equipment is continually becoming obsolete. Small items of equipment can usually be salvaged and disposed of without difficulty but as in other industries the heavy equipment must frequently be demolished in order to make room for newer designs.

Some time ago it was necessary to demolish an entire battery of by-product coke ovens for the purpose of replacing them with a more efficient design. The cast iron and steel portions of this battery were quickly reduced to handling size by means of the cutting blowpipe and the entire job was completed in about six weeks.

Equipment for Development Work

The research laboratories in chemical plants are constantly developing new products and processes. In the laboratory reactions are carried out for the most part in glass apparatus under carefully controlled conditions. Before a new process can be placed in actual production, it must first be tried out on a small scale, using instead of glass beakers and flasks the materials of construction that will be encountered in plant work. Reactions that take place readily in glass have a disturbing habit of behaving quite differently when tried in commercial equipment. Corrosion problems seldom enter into laboratory work as glass is very resistant to chemical action, but the question of the proper material to use in the plant may require long and careful study. The process may also be of such nature as to require the development of a new type of equipment.

In much of this development work, the oxy-acetylene process can give valuable assistance. With the cutting and welding blowpipes, equipment of any desired shape or size can be quickly fabricated from sheet, plate or pipe. The constant changes and modifications that are an inseparable part of development work can be made without loss of time. If there is a question as to which metal or alloy will give best results under the desired operating conditions, the welder can at negligible expense make up equipment of the various materials for comparative test.

Cooperation between development engineer and welding department will result in increased effectiveness of development work. The possibilities are limited only by the amount of thought devoted to this phase of chemical plant work.

Conclusion

Although welding is being used to a considerable extent in the chemical and process industries, relatively few plants have reached the ideal utilization that has been outlined in this paper. The welding industry can aid further progress by making available data that will be helpful to chemical engineers in charge of plant design and to manufacturers who fabricate welded chemical equipment.

Welding in the Plumbing, Heating and Ventilating Industries*

SAMUEL E. DIBBLE†

WELDING in the Plumbing, Heating and Ventilating Industries is rapidly making a place for itself by adapting the skill and technique of torch manipulation to the requirements of good practice in pipefitting. Hardly a convention of the various Plumbing-Heating Industries' organizations meets without some mention of the application of welding in its field. At the Carnegie Institute of Technology, welding has been taught in the Heating, Plumbing and Ventilation Departments since 1917. In the early days of teaching this subject I found no supporters for the welding torch and its application to piping within a building. Such matters as fire hazards, weakness of welds, absorption of expansion and contraction, durability, excessive costs, and lack of welders were advanced as impassible barriers through which the progress of welding could not penetrate. These obstacles are not as great today. The fire hazard is no longer one of concern in the modern concrete and steel construction. The other barriers have one by one been broken down, so that now there are many supporters in the heating and ventilating field for a welded job, and for the teaching of welding to young men interested in plumbing and heating.

The heating industry is not holding welding back on account of its lack of application, but on account of the tremendous turn-over involved, both of sales and materials. The steamfitters and sheetmetal workers and plumbers must learn how to weld. Welders cannot be brought into the industry with success on account of the labor conditions. The art of welding or more specifically the welding torch is looked upon as a tool for the mechanic to use. This is a correct thought. How impossible it would be to bring a welder into every trade that can use welding! Keeping in mind the welding torch as a tool, it should enter each skilled trade in

*Paper presented at Annual Meeting, A. W. S., April, 1929.
†Ahrens Professor of Plumbing, Heating & Ventilating, Carnegie Institute of Technology.

such a manner that the skilled workers will accept it as a working tool and become proficient in its use. The plumbing, heating and ventilating industries which play such an important part in the comfort and health of human beings, cannot afford to experiment, for in doing so some human being may die from poor installations or may be subject to ill health throughout life. This then is entirely different from the industry where merely a loss of money may be the result of experiments. To perfect the skill and knowledge of steamfitters and plumbers requires five years of apprenticeship. The welding torch must be placed in the hands of men skilled in the plumbing and heating trades. With the torch should go complete information—to its application. The welding and cutting torches, gases, regulators, etc., have been perfected to the extent of using them on construction work. The welding industry must not stop its development there. The welding industry must develop its application. A steamfitter can take a perfect torch, regulators, and gases and soon become proficient in welding but will quickly discard it as of no value to him. He must be shown exactly where and how to use it, and of what advantage it is. These questions and many others must be answered by the welding industry if it expects to have its tools used. Many jobs are now being installed using only the welding torch, but each contractor is making blunders and correcting them. The uncertainty of welding keeps the contractors from using it.

Welders cannot be brought into the heating, ventilating and plumbing industry trades for at least two reasons:

1. Every welder brought in to do work takes that much work away from the steamfitter, or other mechanic.
2. The welder seeks only to make a perfect weld and knows nothing about flow of water, steam or air, nor about the various types of systems and equipment. I repeat that the skill of welding must be given to the skilled mechanic.

Training the skilled mechanic in welding, cutting, and bending will take time. It cannot be done in two or three years, yet it will be in time. There is no real hurry to force welding into these skilled trades. It must come gradually if for no other reason than to allow adjustments of manufacturer's output of articles now used. To give the welding industry some idea of how the heating and piping contractor feels about this, I read a statement from the February issue of their official bulletin:

"The Value of Welding"

"It is unfortunate that the members of the Heating and Piping Contractors National Association are so slow in availing themselves of the opportunities held out by the 'Science and Art of Fusion Welding,' as it applies to piping installations. A good Arc or Oxy-Acetylene outfit, in the hands of an experienced operator, is one of the most valuable assets on any kind of a piping job. Its possibilities are almost unlimited. The physical effort required to install the average welded job is 60 per cent less than that required on a screwed joint job.

"Welding does away with bulky, unsightly fittings of uncertain quality. It does away with costly repairs and replacements. It makes it possible

to install pipe where it would not be possible to install it with fittings. It enables the welder to make fittings and bends of good appearance and of unquestionable strength and quality, as well as joints that will positively be tight, and stay tight. If it becomes necessary to remove a section of piping at any time, this can be done more readily and quicker with the torch, than by the old methods.

"The lack of interest in welding by the members of the association, is probably due to a lack of knowledge of its merits and possibilities.

"There is available, through the medium of National Headquarters, volumes of simple and dependable instructions and data, which by a few hours' study would enable anyone interested, to organize a welding department in his shop.

"While the joining together of pipe by 'Autogenous Welding' is comparatively new (1910), it has passed the experimental stages, and through the efforts of some of the most outstanding and dependable engineers, and others interested in the practical application of welding, its dependability when properly applied is unquestionable. We must, however, bear in mind that the human equation enters into the successful application of this as well as any other art, so that it is essentially necessary to have not only properly qualified welders, but also intelligent supervision on the part of those interested in producing economical results, consistent with the best and most dependable workmanship.

"Manufacturers of welding necessities are ever ready to cooperate with and advise those who are interested in adopting and promoting the 'Art of Welding,' and this service is generally free."—J. A. McLeod, member of the Subcommittee on Welding; Heating and Piping Contractors National Association; Jan. 21, 1929.

This statement has a very significant meaning. The heating industry is applying the art of welding in a way that will bring success to its efforts. A committee on welding has been appointed and they have functioned to the extent of designing a flange that can be used in welded jobs. To have a new art develop and be recognized by the industry, and then have that industry proceed to apply it in a well-defined manner is far better than allowing it to drift in and, after many sad failures, become part of the trade.

The application of welding and pipe bending offers to the consumer a better heating job for the following reasons. According to Rietschel and Brabbee the coefficient of resistance to the flow of liquids in a ninety deg. fitting is 1.0, while that of a ninety deg. bend, the radius of which is (R=50), five times the diameter of pipe, is zero. Applying this fact to the heating work it is possible to greatly reduce the friction in pipe lines by bending all changes in direction and not use fittings. This friction reduction is a very important matter in heating systems as the motive force, especially in hot water heating systems, is so extremely small that serious results often occur because of the use of a great number of fittings. Excessive friction makes a sluggish system, interferes with circulation, and causes an imperfectly balanced system. By the use of bends a freer flow of water, steam or air can be obtained.

The American Society of Heating and Ventilating Engineers in their research laboratory at Pittsburgh determined by experimentation that a branch "T" enlarged at the point of branch off-take reduces turbulence to zero, when used in the average heating system. There are no fittings made to make up this condition. However, with the aid of the welding torch every branch can be made in that manner. Bending and welding piping will greatly help in making the vital things of heating systems function better. Not only by reducing friction in the practice of pipe bending but by causing fewer joints to be made on the job, we can save on the cost of installation.

The technique of welding and its exact application to plumbing and heating must be perfected by the plumbing and heating engineer. I have had the pleasure of discussing this problem of gas and electric welding with the pipe welding departments of every large welding equipment and gas manufacturer. For those who wish information on pipe welding that has been done the above mentioned departments can furnish it, but for information as to the direct application to embody the principles of heating there is no place to go. Some agency or experimental work should be carried on by the welding industry to determine ways and means to accomplish correct results. I will speak more of this later.

I erected a steam heating sanitary pressure system in my laboratory about four years ago with the aid of a large manufacturer. This system was the cause of considerable comment, a picture of it and a detailed account appeared in practically every trade paper. This system gave the industry something to talk about and every detail of its erection was discussed. That was four years ago. Today the same thing must be done on a wider scale. The flow of steam and water through a job with fittings and checked with a welded job must be studied. While the plumbing and heating industry is interested in the physical development of the art of welding it is more interested in the correct flow of steam and distribution of water to produce a perfect system.

The reinforced "T" is used where expansion and contraction are liable to be exerted at the branch and main connection. The braces aid in throwing the movement to some other straight pipe section. This connection is necessary only where extreme conditions exist.

Ninety deg. bends can be made in many ways. In heating work, however, the major idea being to lighten and cause easy flow of water and steam, the two-piece should never be used. The pipe can in small sizes, be bent to the desired angle, or "T T_2" Tube Turns can be used.

The labor situation is one which must be understood and dealt with in a fair manner. Welding will be used more or less in the heating field —only in direct proportion as the steamfitters become skilled in the art of gas and electric welding as it applies to their trade. The welding industry must employ steamfitters and heating men, develop them in the art of welding as it applies, and then send them out to instruct other steamfitters. Welding schools similar to the one at the Carnegie Institute of Technology should be fostered by this industry to train steamfitters.

COURSES IN WELDING FOR STEAMFITTERS

Elementary Course: This course is to cover gas welding and cutting of steel.

1. Lecture on gases and equipment.
2. Demonstration of connecting and lighting torch.
3. On piece of pipe demonstrate nipple weld. (Student do same.)
4. Student cut grooves in pipe and fill same with filler rod.
5. Weld two pieces of pipe together—continue until deposited metal and penetration are satisfactory.
6. Demonstrate cutting of steel pipe. (Student do same.)
7. Make "T" joint.
8. Make 45 deg. ell.
9. Make "Y" joint.
10. Make double "T" joints.
11. Make double "Y" joints.
12. Lecture on application of welding and cutting.
13. Practice on 4-in. pipe—"T" joint.
14. Practice on 4-in. pipe—"Y" joint.

This course to be repeated until perfection in skill is obtained.

Advanced Course.

1. Lecture on metallurgy (study of metals).
2. Weld two pieces of pipe and pull apart—(in testing machine.)
3. Weld two pieces of pipe and test for tightness—(in hydraulic.)
4. Continue above until welds hold.
5. Continue above until welds hold.
6. Make round joint—with pipe above head.
7. Make branch joint in corner.
8. Bend a 1½-in. pipe to exact measure—(calculate length before bending.)
9. From 4-in. main tap in, bend and weld 1½-in. pipe for branch main for riser and radiator connection.
10. Make 6-in. ell.
11. Make 6-in. "Y."
12. Cut with template a 4-in. "T" branch into 6-in.
13. Cut with template a 3-in. "T" branch into 6-in.
14. Cut with template a 4-in. "Y" branch into 6-in.
15. Make a three-piece 4-in. 90 deg. bend.
16. Cost of gas and rods for welds.

This course to be repeated until perfection in skill is attained.

A welding school of this kind should be so equipped that each student will have a torch or welding station. Twenty-five students should have at least twenty torches. It is better to have twelve students with ten torches. This number is about all an instructor can attend to in a two-hour period. Twelve students can have about three minutes of the instructor's time every half hour.

There is another distinct project which must be carried out and that is this: Some group or individual must erect an experimental heating system, a small system using 6-in. pipe and sizes smaller. Try out on

this job many experiments of types of welds and methods of performance, and then report in detail this information, not to the welding groups and papers, but to the heating, ventilating and plumbing groups and papers.

Such things as cost per joint, labor and gas, cost per square foot radiation, labor per radiator, strength, ease of application, etc., will go far toward wiping out irregulatorities and perfecting ways and means for application of welding to low pressure pipe systems.

S. E. DIBBLE.

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